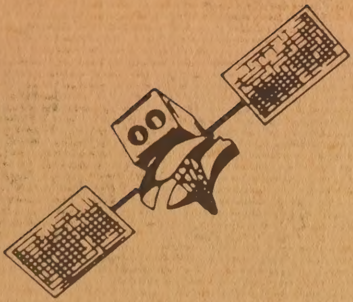
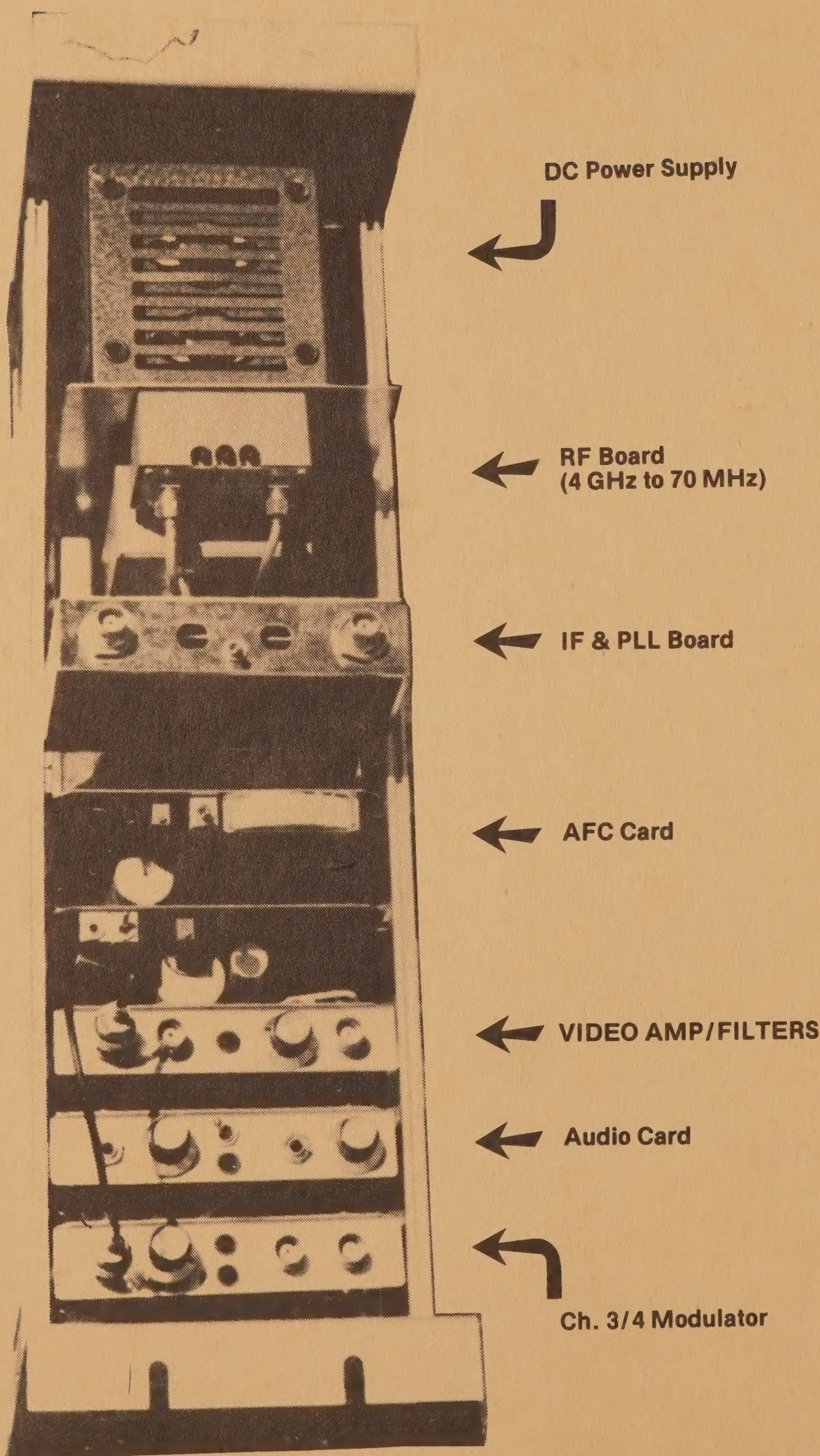


THE HOWARD TERMINAL

...a manual to guide you in constructing your own satellite television reception terminal for under $1000 cost electronics.

PRICE: $30.00 per Copy



THE COMPLETE HOWARD TERMINAL RECEIVER MOUNTED IN 19'' RACK CARD CAGE

WELCOME TO A NEW WORLD!

The purpose of this manual is to provide the serious satellite television fan with the necessary 'tools' to allow duplication of a professional grade TVRO terminal that has been in operation for nearly three years at the home of Taylor Howard.

Recent advances in microwave technology coupled with intense competition have made the cost of private satellite television receive terminals tumble rapidly during the year 1979. At the present time these advances add up to produce the hardware bits and pieces so that a reasonably technically competent individual can duplicate the terminal described here.

There are a number of motivations for building a private satellite television terminal ranging from the 'criminal' to the purely technological. And there is a vast middle ground occupied by those who want 'something for nothing', special sporting events not available on regular television, religious groups interested in the multiple channels of twenty four hour per day gospel and a surprisingly large number of people who, like Taylor Howard, want to be in the mainstream of life but who, because of their location can never hope to be connected to a cable television system or to a MDS commercial system.

The advances in the technology itself come rapidly. There is a direct and obvious relationship between the number of individual people who are working on this type of project, independently from others, and the advances reported. In the course of the past two to three years the technology of receiving satellite television signals has moved from the realm of the laboratory scientist to the garage workshop builder. Not every individual setting out to create his own version of a satellite television terminal in his garage workshop can hope to discover some significant breakthrough in the technology. However there is both a challenge and an opportunity for everyone so dedicated to do so and as many thousands of individuals tackle this challenge there will be more technology reported weekly and daily. All of this will impact on the way we perceive low cost, private satellite television terminals in the years ahead.

This manual, from Satellite Television Technology, is but the forerunner in what will ultimately become the technology base for the development of truly universal, low cost satellite (to home) television for all of North America. Perhaps, ultimately, a few thousand pioneers like yourself will have assembled terminals identical to or essentially like the Howard Terminal described here. As new advances come, so too will come new manuals and new outlets for technology material relating to this new field. It is the nature of technology that each new significant advance will bring 'cheaper' and 'simpler' hardware. By tackling this project at this point in time, with the technology now available, you are indeed a 'pioneer'. There are tens of millions of American homes equipped with television receivers but fewer than 10,000 equipped with satellite television receive terminals. You will be in the elite of the elite when your home is equipped with satellite television ... in the 1/100th of 1% region!

And this note. Each individual purchasing this Howard Terminal Manual is extended the opportunity to have on-going technical assistance from the developer of this terminal, Taylor Howard, for a minimal consulting fee. A consulting fee registration form appears in the rear of this manual. Be warned however - that consulting from Howard extends only to those who intend to exactly duplicate the instructions in this manual. For those who are only comfortable by modifying a circuit worked out by someone else, we suggest that you skip the consulting offer. Howard knows and understands his own satellite TV receive terminal intimately; but he cannot be expected to diagnose problems created by modifications worked out by others without benefit of his own experience or counsel.

THE HOWARD TERMINAL MANUAL

Produced and distributed by Satellite Television Technology, P. O. Box 2476, Napa, California 94558. Price is $30 per copy and that includes for the purchaser the option to engage TVRO designer H. T. Howard for additional consultation for a nominal $25 consulting fee.

TOPIC MATTER	PAGE NUMBER

THE COVER - H. Taylor Howard and his modular, original, state-of-the-art fully frequency agile satellite television receiver. You can duplicate it. Probably for less that $1,000 and around 50 hours of your time. And it sure beats watching reruns of Maude!

INTRODUCTION

This manual is being prepared in response to hundreds of inquiries about communication satellites and the reception of their signals. This manual is the outgrowth of an experimental system designed and developed by Taylor Howard over several years. The terminal has been created for engineering research and any other use has been purely a side benefit. It should be possible for persons with a combination of technical education and practical experience to duplicate this system. This is not a project for the novice to electronics or the individual who takes ten hours to assemble a two hour Heathkit project.

There are a number (more than thirty at this writing) of communication satellites in orbit above the Earth's equator at a height of 22,300 miles. This orbital altitude was chosen because, at that height, the satellite has a period of revolution around the earth which is precisely the same as the earth's own rotation period. The satellites, therefore, appear to 'stand still' in the sky to the earth based observer. Further, the commercial satellites have station-keeping thrustors on board and by using these thrustors ground controllers can insure that the satellites are kept within a 'station keeping box' of approximately 70 miles on a side, with their receiving and transmitting antennas always pointed back towards the exact same spot on earth. This means that the earth based receiving (or transmitting) antennas installed to function with the geostationary satellites can be aimed once at the satellite and then left alone.

The satellites of interest to stations in North America are listed along with their positions in Table 1. They all radiate downlink (satellite to ground) signals in the 3.7 to 4.2 GHz (3,700 to 4,200 MHz) band. The frequency for each channel is shown in Table 2. Note that SATCOM I and II (and late in 1979 SATCOM III), as well as the three COMSTAR 'birds, have twice the number of channels as the others because they employ a frequency 'reuse' scheme made possible by overlapping channels and using two separate (vertical and horizontal) orthogonal linear polarizations. In general the spacecraft antennas are designed to cover the USA with the peak of the beam located towards the center of the United States in the upper midwest; with signals falling off (typically) by 3 to 4 dB on both coasts. There are also spot beams to cover Hawaii and in the case of WESTAR Alaska as well. These spot beams are typically 8 to 12 dB lower in level than the main beam centers and this means that receiving sites located in Hawaii (in particular) must have larger, more effective antennas to reproduce high quality television pictures from the system. (Alaska reception tends to be as good or even slightly better than most portions of the lower 48 states primarily with the SATCOM birds because RCA is very much involved in contracting for Alaskan telecommunications service.)

The terminal design presented in this manual is based on a satellite EIRP of plus (+) 35 dBw. Signal strength does vary with location, and from satellite to satellite. Signal strength with the RCA series birds also varies as a function of transponder number since RCA groups six transponders (channels) on each of four separate transmitting antennas on board the satellite. A full set of eleven EIRP maps covering the WESTAR, ANIK (Canada) and RCA satellites is available for $10.00 postpaid from: EIRP MAPS, % CATJ Magazine, Suite 106, 4209 NW 23rd, Oklahoma City, Oklahoma 73107. Close study of these maps will reveal that the EIRP's available throughout North America vary from a high of +37 dBw to a low of +25 dBw with Hawaii generally the loser in this accounting. Since spacecraft antennas are steerable by ground command, coverage can change from time to time as commercial requirements of the satellite operators change. For calculation of antenna pointing angles from your location to the various satellites it is suggested that you request a "Custom TVRO Antenna Pointing Chart" from CATJ Magazine, Suite 106, 4209 NW 23rd, Oklahoma City, Oklahoma 73107. Send a check for $4 and your geographical coordinates (the longitude and the latitude to the nearest minute). You will receive back a computer derived antenna pointing chart that will show your full 'satellite sky' from horizon to

horizon. Or you may manually compute your own antenna pointing angles by consulting the article by William Johnston entitled "Locating Geosynchronous Satellites" appearing the the March 1978 QST; pages 23-25.

The video broadcast from these satellites is a much different format than used in earth-based broadcasts and, thus, needs a fair amount of electronic massage prior to viewing. It is transmitted as wideband FM with a peak to peak deviation of 21.5 MHz and an audio subcarrier of either 6.2 or 6.8 MHz (typically). To achieve good color and to recover most of the energy transmitted an IF bandwidth of about 30 MHz should be utilized although excellent results can be obtained with bandwidths as narrow as 22 MHz and some designers report improvement in baseband pictures with IF bandwidths as narrow as 15 MHz. Recovery of the transmitted information is further complicated by the fact that the whole carrier is FMed or 'dithered' at a 30 Hz rate over a 1 MHz bandwidth to reduce 'spectral density' on earth. This is an interference reduction technique employed to 'protect' terrestrial (common carrier) point to point microwave circuits operating in the same (3.7 to 4.2 GHz) frequency range. Therefore after discrimination (detection to baseband) the sync tips must be clamped prior to processing in normal television circuitry. The clamping serves to remove the 30 Hz 'dither'.

Table 1

Satellite Name -	SATCOM I	WESTAR II	SATCOM II	WESTAR I	ANIK III (*)
Manufacturer -	RCA	Hughes	RCA	Hughes	Hughes
Owner -	RCA	Western Union	RCA	Western Union	Telesat Canada
Longitude -	135 W	123.5 W	119 W	99 W	114 W
# of Channels -	24	12	24	12	12
Audio Subcarriers -	6.8	6.2 or 6.8	6.8 or 6.2	6.8 or 6.2	6.8

* - ANIK B is located at 109 degrees west and carries some television; ANIK II is a spare in orbit at 107 degrees west and ANIK I is a to-be-retired bird at 104 degrees west.

Table 2

CHANNEL NUMBER	HUGHES CENTER FREQUENCY	RCA CENTER FREQUENCY (vertical)	RCA CENTER FREQUENCY (horizontal)	CHANNEL NUMBER	RCA CENTER FREQUENCY (vertical)	RCA CENTER FREQUENCY (horizontal)
1	3720 MHz	3720 MHz		13	3960 MHz	
2	3760 "		3740 MHz	14		3980 MHz
3	3800 "	3760 "		15	4000 "	
4	3840 "		3780 "	16		4020 "
5	3880 "	3800 "		17	4040 "	
6	3920 "		3820 "	18		4060 "
7	3960 "	3840 "		19	4080 "	
8	4000 "		3860 "	20		4100 "
9	4040 "	3880 "		21	4120 "	
10	4080 "		3900 "	22		4140 "
11	4120 "	3920 "		23	4160 "	
12	4160 "		3940 "	24		4180 "

THE RECEIVING SYSTEM

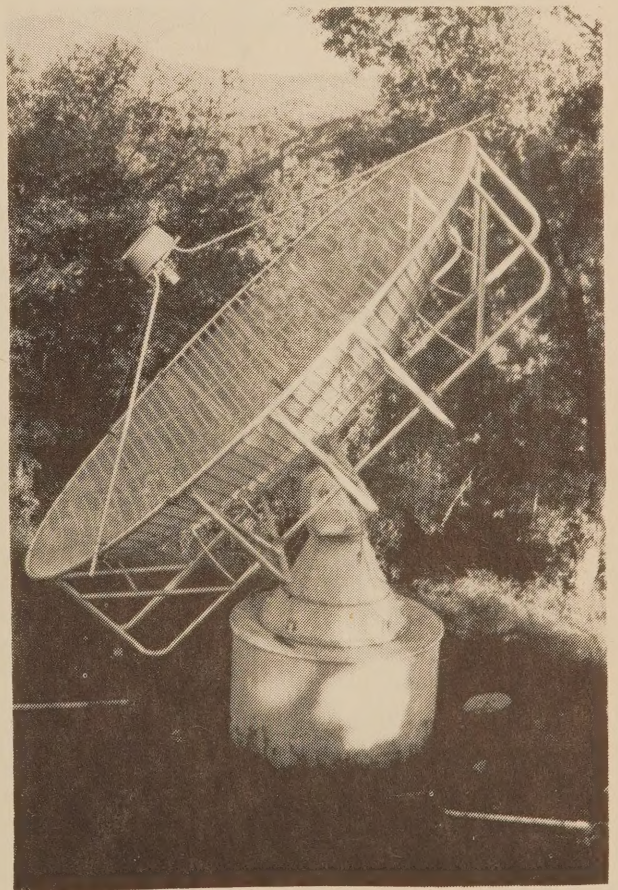
The block diagram of a working system is shown here. The following paragraphs will describe the system, each block, and the circuit diagrams in detail.

Parabolic Reflector - The first element of the system is the parabolic reflector antenna. Since we desire to achieve maximum gain from the antenna it is necessary that it be a true parabola and that it be smooth. The maximum deviation from the ideal parabolic surface should be on the order of a sixteenth of a wavelength or about one half of a centimeter. Bettering this by a factor of two can improve the gain by about one half dB and improve beamwidth by about 10%. The surface of the antenna can be solid or mesh. Mesh has mechanical advantages (particularily when the wind blows), and can be considered 'totally reflective' (transmission losses down 30 dB) when the holes are smaller than about half a centimeter. The system under discussion uses an aluminum expanded mesh with holes of 1/4" by 3/8". So that system tradeoffs can be made, Table 3 shows antenna diameters, beamwidths and noise temperature requirement for each size.

PARABOLIC DISH ANTENNA PARAMETERS AND SYSTEM NOISE TEMP (K) REQUIRED AT 4000 MHz

Diameter (feet)	Beamwidth (degrees)	Gain (55%) (dB)	Noise Temp Required (K)
15	1.15	43	300
12	1.40	41	190
10	1.70	39.5	134
8	2.10	37.5	85
6	2.80	35.0	48
3	5.60	29.0	12

TABLE 3



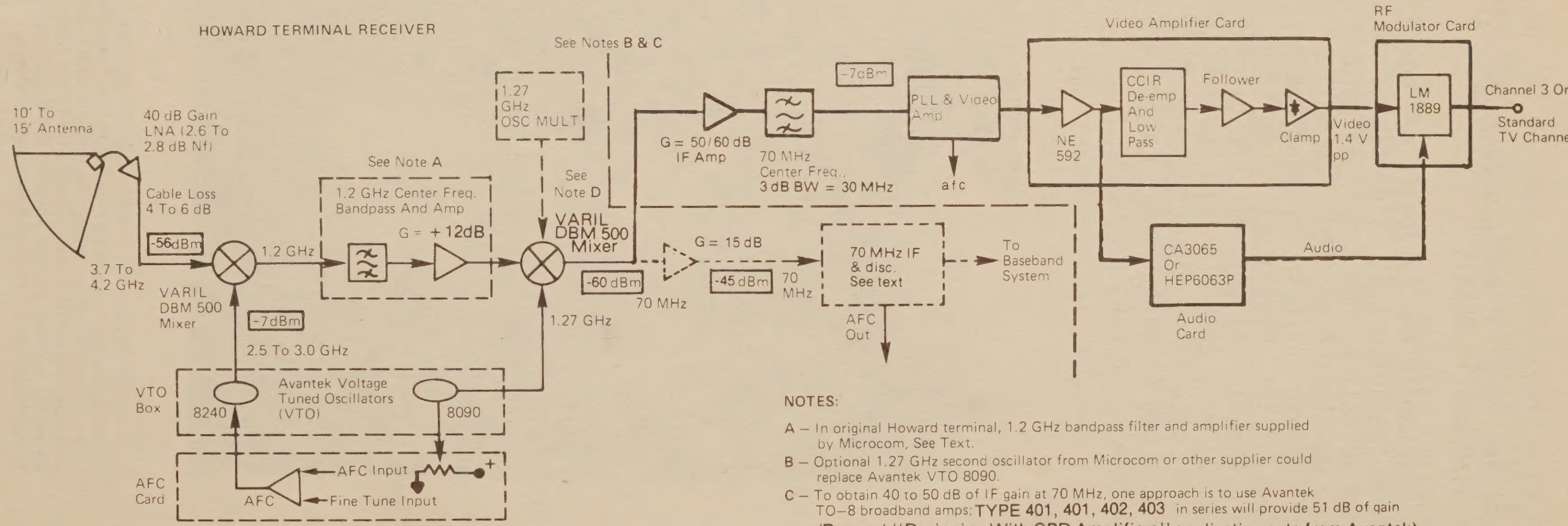
OFF A BATTLESHIP - this very old surplus mount and antenna was discovered by Howard in San Francisco Bay area in a junk yard. After straightening out bent metal and resurfacing dish with mesh he ended up with first class installation for fraction of new antenna cost; plus has advantages of motor driven azimuth and elevation controls.

Notes: Higher gains are possible using optimized Cassegrain configurations which give aperture efficencies of 65% or so.

The noise temperature requirement is based on a +35 dBw signal area and 11 dB c/N_0. In the receiver described in this manual, this will produce a picture without noise.

State of the art GaAs-FET amplifiers have a best case Kelvin noise temperature of between 80 and 90 degrees when uncooled.

Antennas smaller than 8 foot in diameter intercept terrestrial noise in the 300 degree K region; restricting system sensitivity to that 'level'.



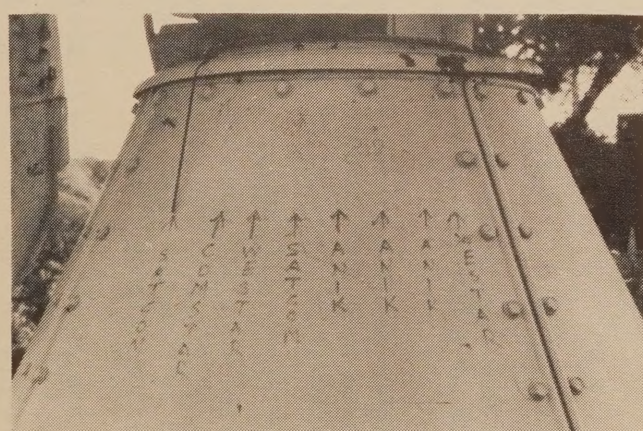
NOTES:

A – In original Howard terminal, 1.2 GHz bandpass filter and amplifier supplied by Microcom, See Text.

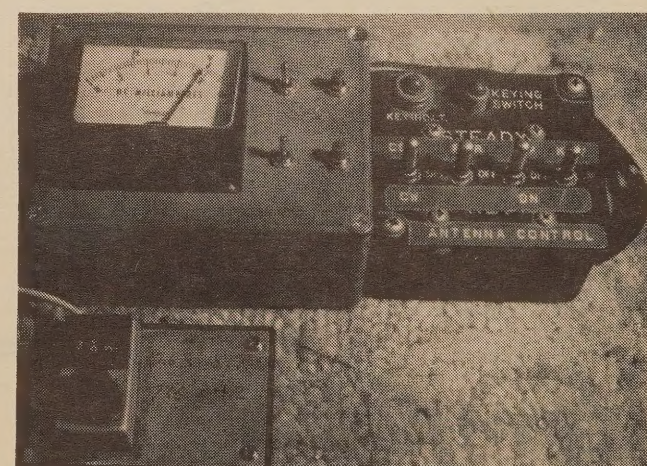
B – Optional 1.27 GHz second oscillator from Microcom or other supplier could replace Avantek VTO 8090.

C – To obtain 40 to 50 dB of IF gain at 70 MHz, one approach is to use Avantek TO–8 broadband amps; TYPE 401, 401, 402, 403 in series will provide 51 dB of gain (Request "Designing With GPD Amplifiers" application note from Avantek)

D - Two approaches to 1.2GHz/baseband shown: portion Above dashed represents present and final Howard terminal system.



8 OF THE 11 - now in operation are marked off on the mount at the Howard terminal (two of the COMSTARs are not shown). Howard's terminal motor-adjusts in azimuth (left and right) and elevation (up and down) from his viewing chair!

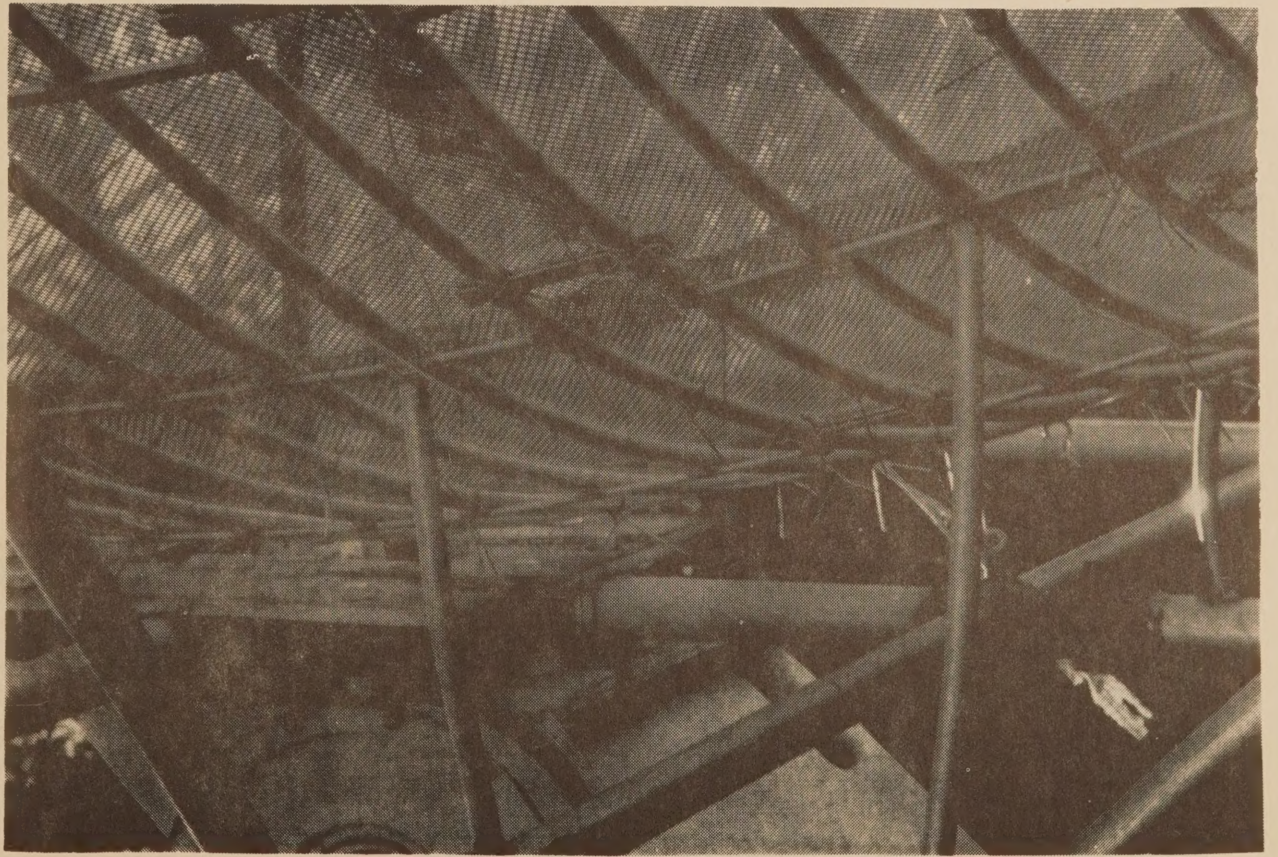


CONTROLS - Upper left controls polarization rotation; upper right is elevation (up and down). Front left is helical pot that drives VCO for transponder changing.

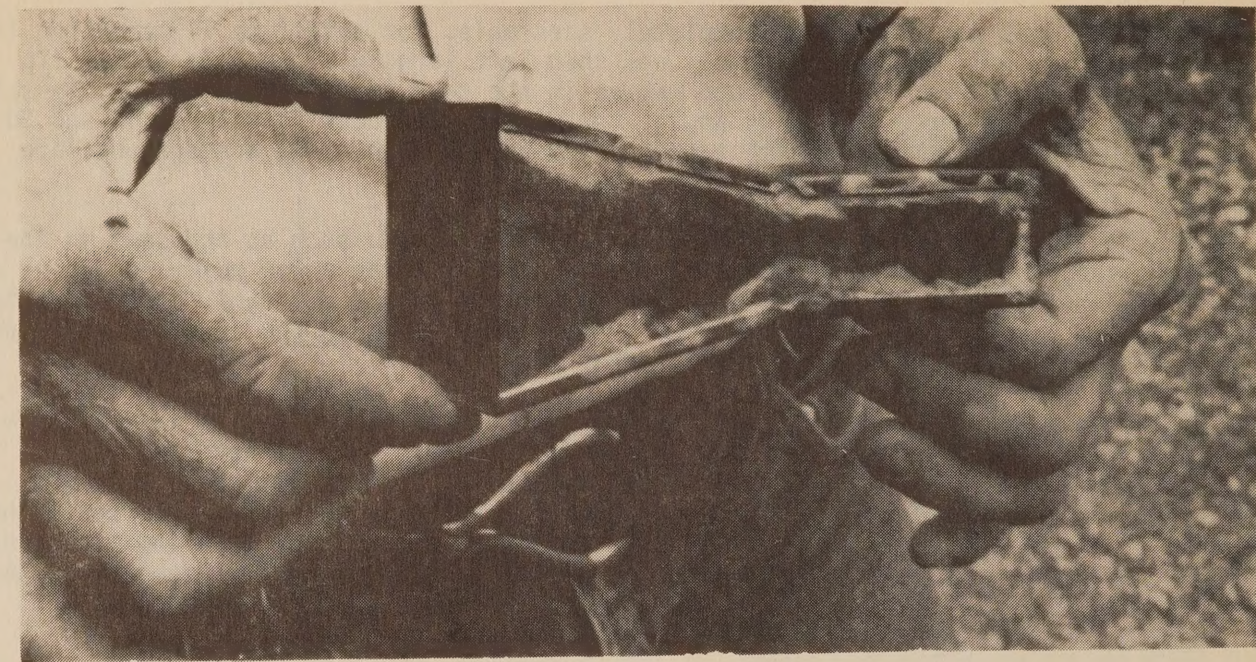
The antenna does not have to be completely steerable. For satellite TV reception it is likely that it will be pointed (once) and then left largely alone. The bottom lip of the antenna could rest on the ground or, as in the case of one swimming pool installation, below ground. Since the 'look angle' for mid-US latitudes is between 30 and 50 degrees above the horizon, many simple (and inexpensive) mechanical arrangements are possible.

It should be noted that arrays of directive elements (i.e. such as one sees in the Yagi or Colinear antenna designs) are not really attractive as a low noise receiving antenna in this frequency band, for feed line (coupling) losses become dominant. Other than the parabola, the 'Horn Antenna' has been used successfully although the required structure is considerably larger for comparable gain than a parabola.

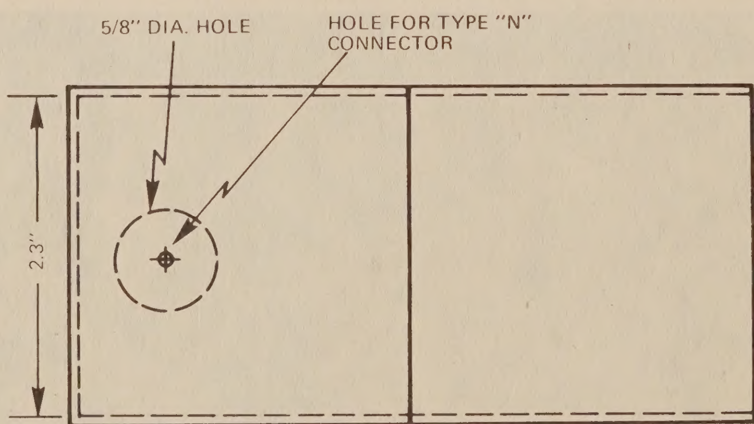
The focused energy from the surface is collected at the feed point by a small horn antenna which can be designed according to standard textbooks. (see Reference Data For Radio Engineers, any edition, under 'horn antennas'. Desired design is one for 10 dB width horn.) A design for a feed horn will be presented here. For reference, the 'standard' waveguide dimensions for this frequency band are 2.29 by 1.15 inches inside. A short waveguide 'section' and a horn can be quickly and easily built from either two sided printed circuit board (G-10) or brass or copper sheet soldered inside and out.



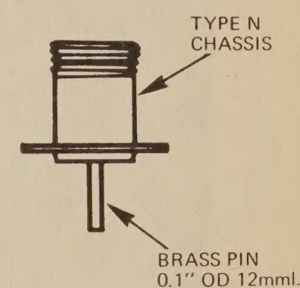
MESH SURFACE DISH - at Howard Terminal has proven to be effective, low cost surface.

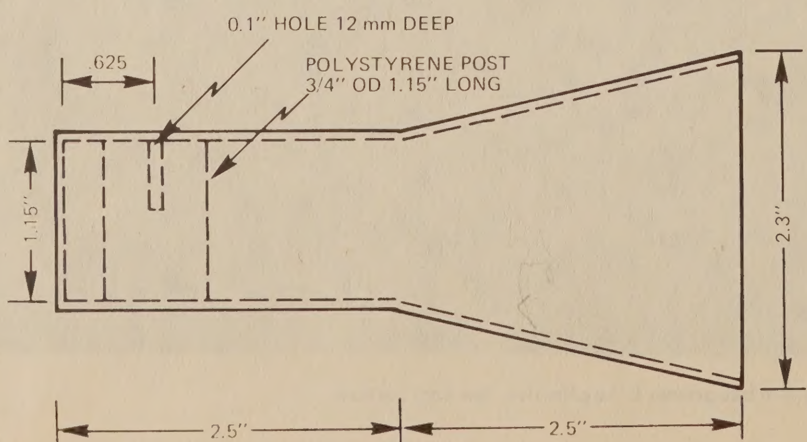


DO IT YOURSELF FEEDHORN - for most commonly available reflector surfaces; see text.

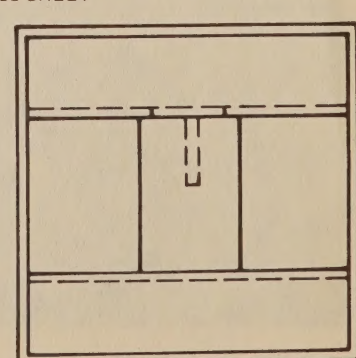


HOWARD TERMINAL FEED HORN





NOTE: MATERIAL 1/16" DOUBLE SIDED PC BOARD, OR COPPER OR BRASS SHEET



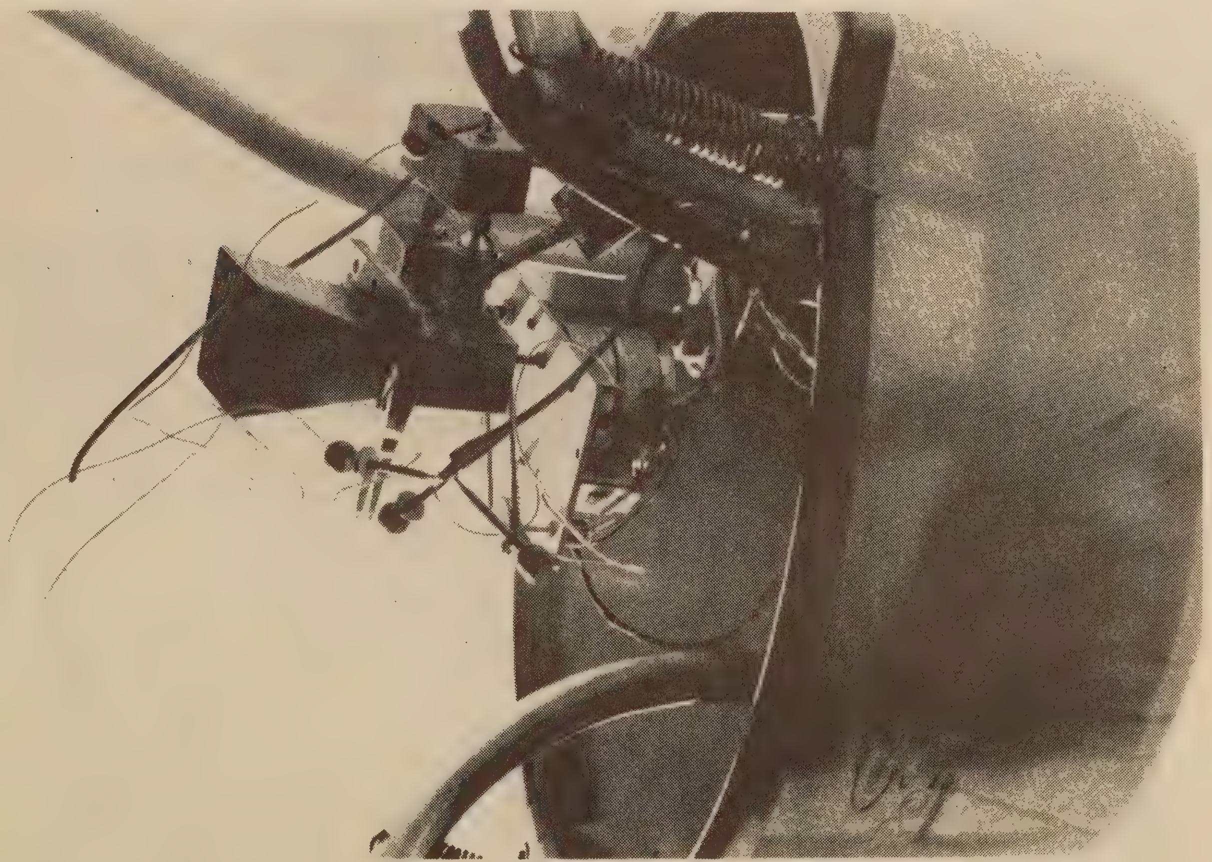
SATELLITE TELEVISION TECHNOLOGY - P. O. Box 2476, Napa, California 94558

Dimensions for a feedhorn usable for f/D ratios from about 0.3 to 0.45 are shown here. This horn could be mounted on three or four support legs along with a small platform for the preamplifier devices. If polarization diversity is required, provision can be made for motor driven 90 degree rotation of the feed horn antenna.

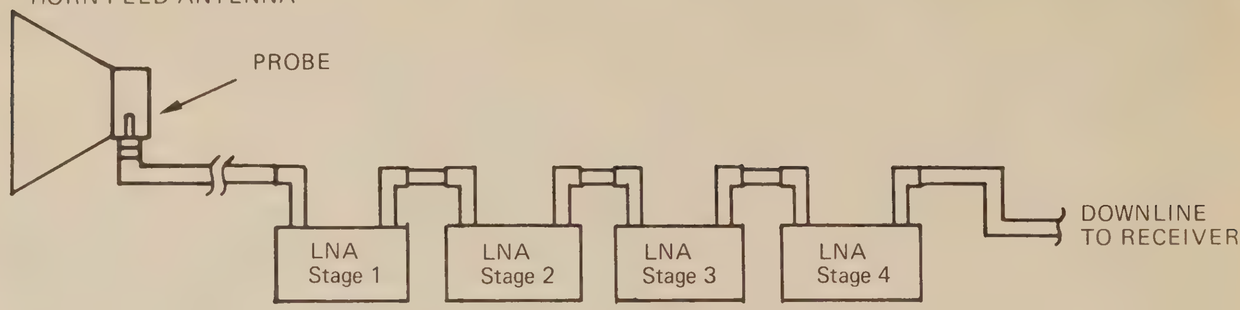
Aside from adherence to a true parabolic shape there is another factor of interest; f/D (this being the ratio of the focal length to the diameter of the dish). A 'focal plane' antenna (parabola) is one where the focus point is in the plane of the antenna opening (i.e. f/D = 0.25). The angle of illumination for the feed is thus 180 degrees; a very wide angle that will be difficult to illuminate (or 'see') with the feed antenna when the goal of the antenna is maximum gain. A 'flat dish' will have an f/D of 0.5 or greater. Over this range the general rule is that deep dishes have low side lobes (i.e. less pick up from off the antenna heading) and lowest system temperatures (system antenna temperature includes 'noise' from the earth which side lobes 'see') while flat, or shallow, antennas have maximum gain. The best compromise for prime focus (or Newtonian) feeds occurs at an f/D of about 0.4. You can calculate the focal length by measuring the diameter and depth of the dish and using the following formula:

$$\text{focal length} = \frac{(\text{radius})^2}{4 \times \text{depth}}$$

The first signal preamplifier is mounted directly on the feed horn so that no transmission loss is incurred. The system described has four cascaded amplifiers to provide more than 40 dB of gain. The first stage utilizes the Hewlett Packard HXTR 6102 bi-polar transistor and subsequent stages use the slightly less expensive HXTR 6101. Mounting these



PLASTIC HORSE FEED BOWL (right) provides weather cover for stacked up LNA stages, feed horn and feed horn rotation system on Howard Terminal dish.

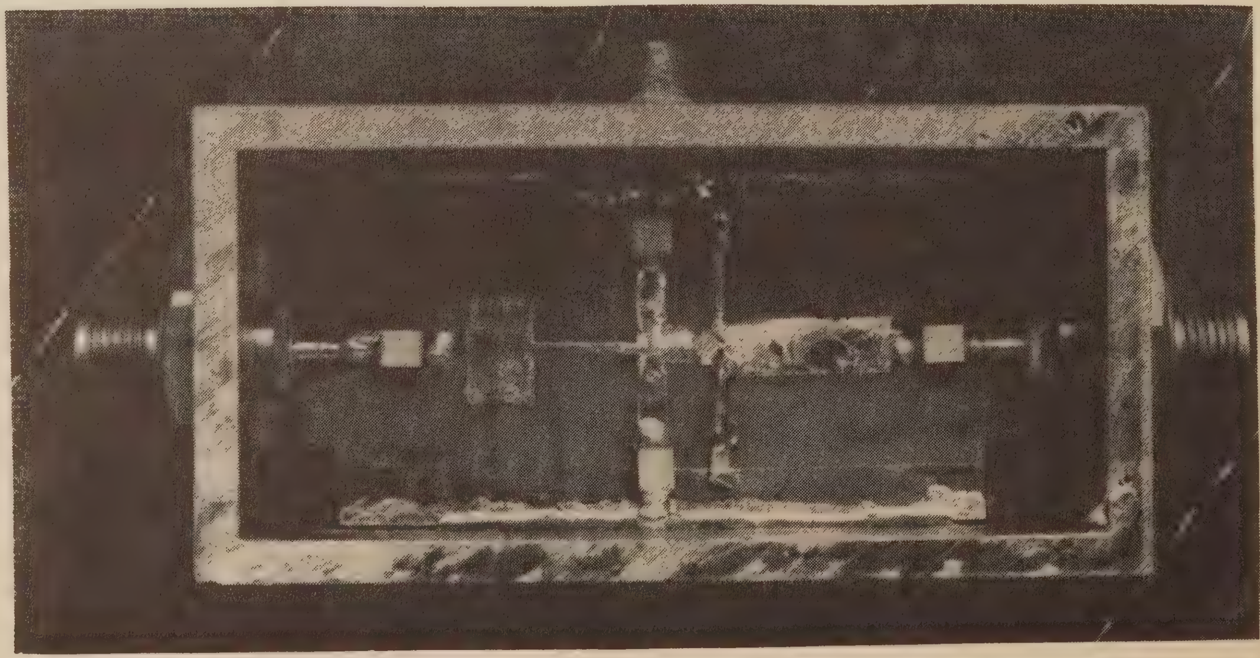


FOUR STAGES ARE CASCADED; EACH IN SEPARATE MODPAK 7055–4 CASE.

amplifiers right at the feed is the key to obtaining low system noise and making certain that the following stages have little effect on system noise temperature. The broadband output is then taken to the first mixer through low loss cable. The total loss of this cable at 4 GHz should be held to less than 6 dB.

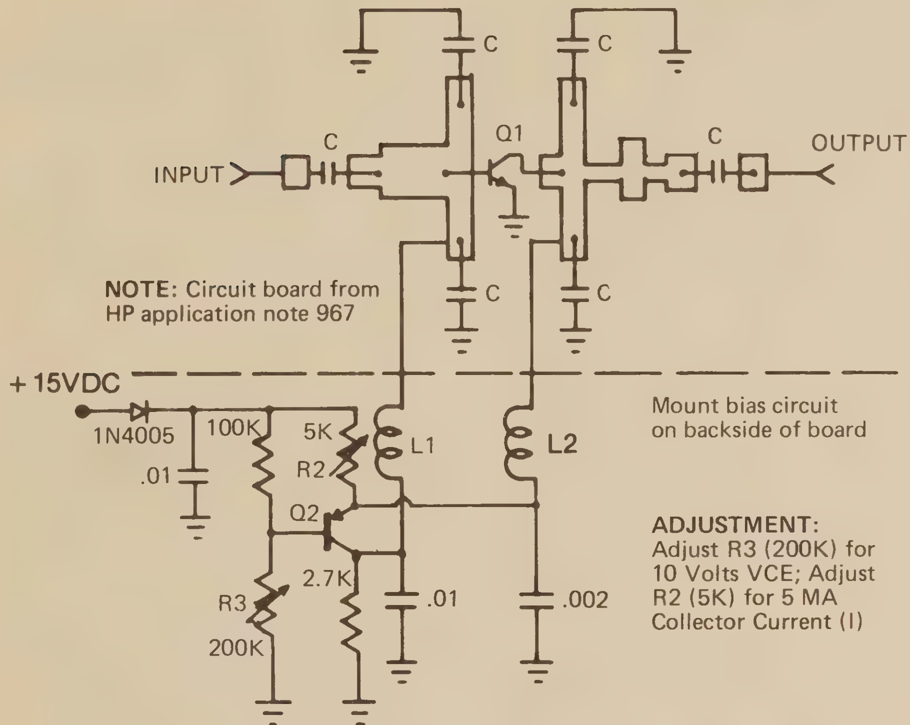
The preamplifiers can be constructed from Hewlett Packard Application Note # 967 although the capacitors specified in that note are no longer manufactured and the other parts and the PC board material are hard to obtain in small quanities. The amplifier stage circuit diagram, board layout and parts list are shown here. Capacitors currently available are referenced in the suppliers addendum. A PC board negative is also shown here. If you wish board (Duroid board must be used at this frequency; normal G-10 board will not function at 4 GHz), small quanities are available directly from Taylor Howard. Etched boards and some capacitors are available for a reasonable fee from: Robert M. Coleman, RFD 3, Box 58-A, Travelers Rest, S.C. 29690.

At this point it should be mentioned that there have been many discussions over the



SINGLE STAGE BI-POLAR LNA - using HXTR series devices from Hewlett Packard. Input to right, output to left.

HOWARD TERMINAL BI–POLAR LNA STAGE



NOTE: Circuit board from HP application note 967

Mount bias circuit on backside of board

ADJUSTMENT:
Adjust R3 (200K) for 10 Volts VCE; Adjust R2 (5K) for 5 MA Collector Current (I)

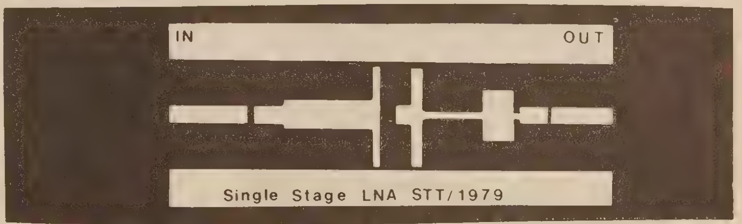
NOTE: All caps in bias cir. 5% ceramic disc
Q2 = 2N3906 or equivilent PNP

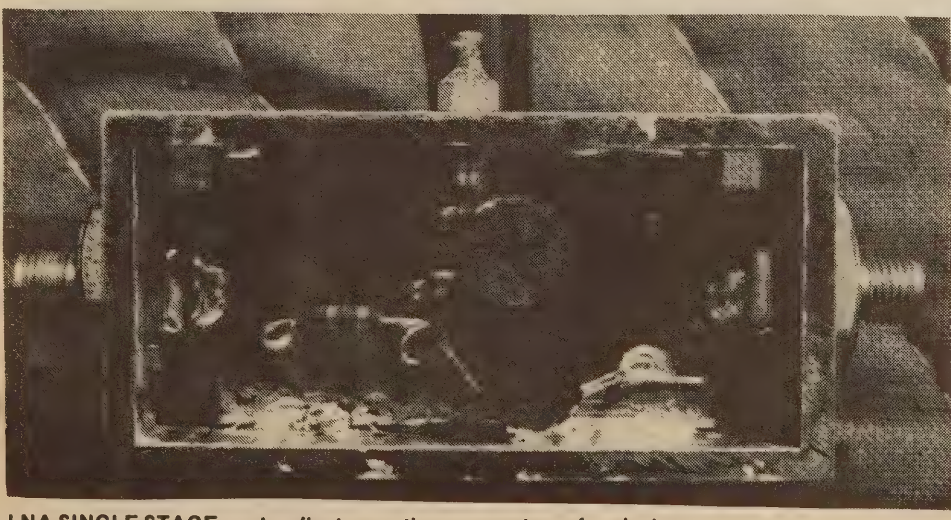
PC Board = MUST BE Duroid .031

C =DI 6B 102 M 50P
(See Supplier List)
Q1 =Hewlett Packard
HXTR 6101, OR, 6102.

NOTE:
Aertech 6101, 6102 require modification to circuit board. Contact Taylor Howard.

L1,2 =
Wind 2 turns 0.1''diameter in Q2 collector and emitter leads before inserting them through board



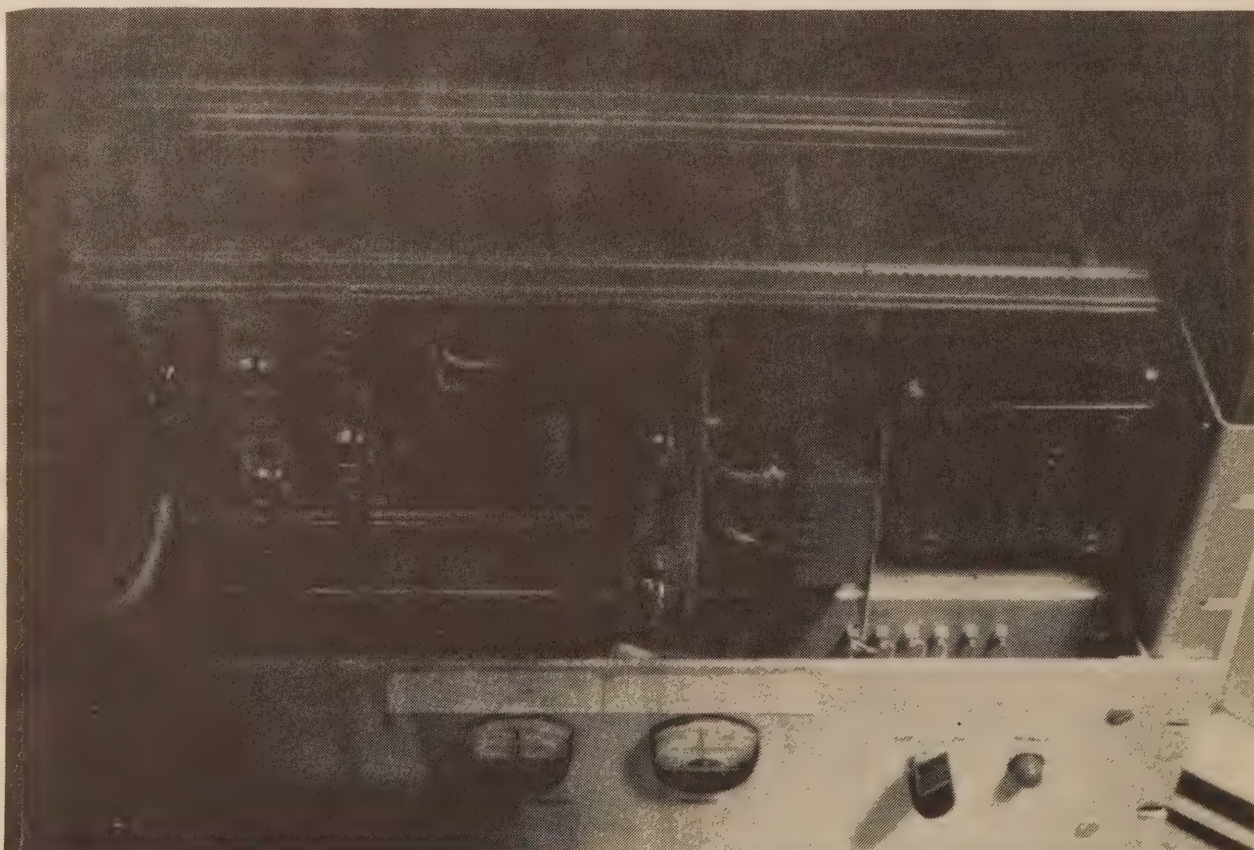


LNA SINGLE STAGE - pots adjust operating parameters of each stage

years on just how much of the system should be located at the feed point. It may be possible, for instance, to eliminate one amplifier stage if the first mixer and its associated oscillator are also located there. In some applications it has been possible to locate the entire system at the feed point. The question is, where do you draw the line? Long experience of climbing ladders in bad weather for trouble shooting suggests that the minimum amount of electronics be located at the feed; that minimum is 30 to 50 dB of gain in a trouble free configuration coming out to the main electronics in an area where bench space for test equipment and circuit diagrams is available. This is not an independent discovery of Taylor Howard, for the commercial industry standard is the same. However, as reliability increases and low cost systems come to the fore this trend will totally reverse with everything except the picture being up there!

When this system was into an operational mode and no further refinements were made, the cost of the Hewlett Packard bi-polar HXTR transistor series was in the $80 to $100 region. More recently these prices have dropped through some HP outlets, largely because a competitive device has come on the market from Aertech, Inc. (825 Stewart Drive, Sunnyvale, Ca. 94086). The Aertech ABT 6102 and ABT 6101 are now available; the 6102 is $31 and the 6101 is $25. Their minimum order is $50 (which works out about right for two stages).

Yet two other options are available if you are not worried about spending some money for a commercial LNA that will 'plug' directly into the system described here. DEXCEL Corp. 2285-C Martin Ave., Santa Clara, Ca. 95050 has announced their model

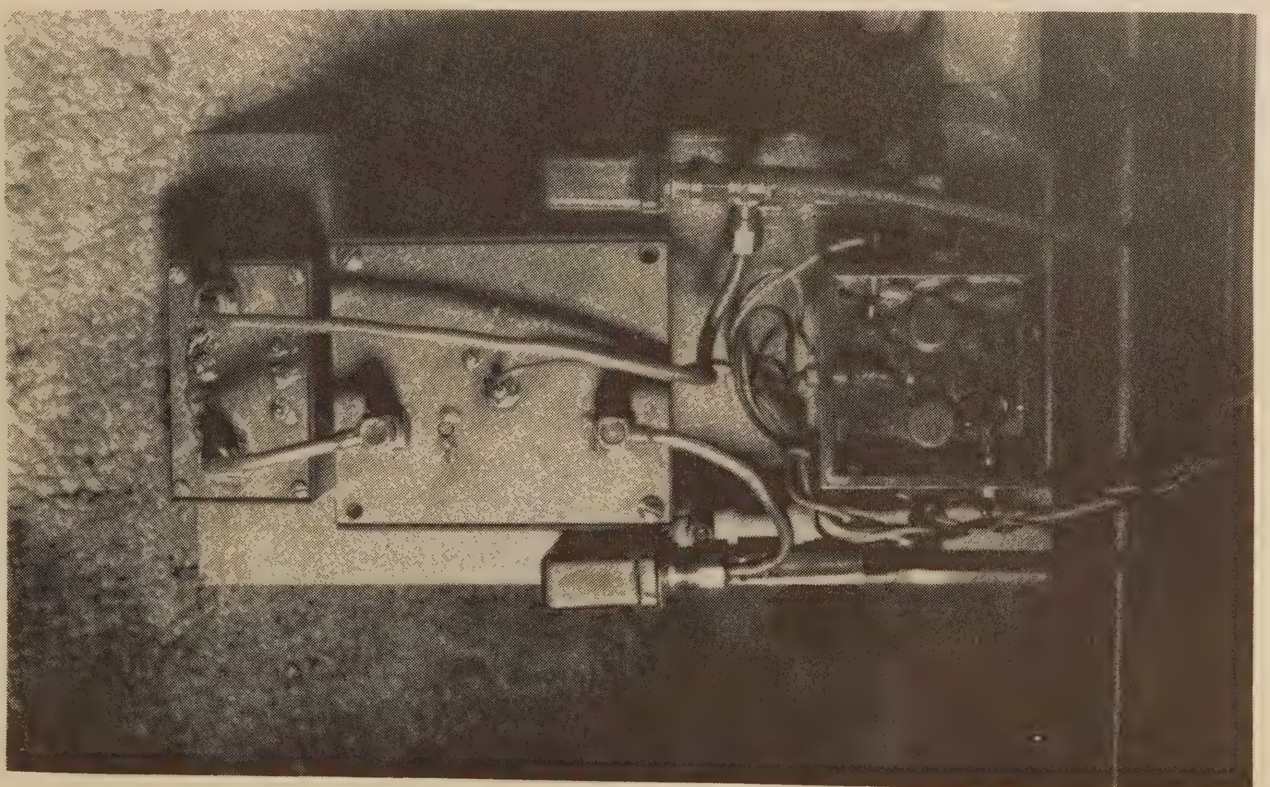


FULL HOWARD RECEIVER - left to right: Channel 3 (or 4) modulator, Audio Card, Video Amp and filters, AFC card (hidden), If and PLL card, 1200 MHz portion with VCO's, and DC power supply.

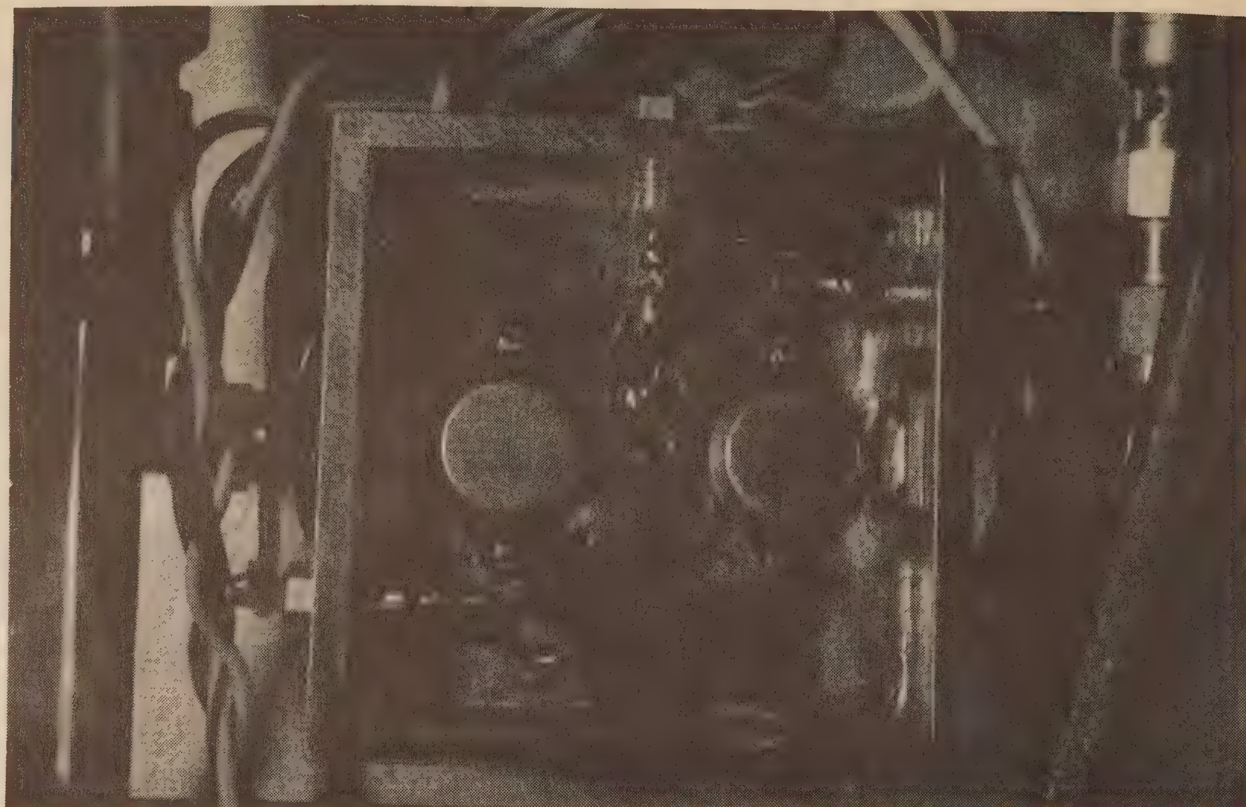
DXA-3091-01 low noise amplifier which they guarantee to have 30 dB of gain and a 150 degree Kelvin noise temperature performance. The initial list price announced was $995. Another major supplier of LNAs, Scientific Communications, Inc. (3425 Kingsley Road, Garland, Texas 75041) recently announced a price slash on their model SCF-395-50D LNA (150 degree K at 50 dB of gain) to $995 and their model SCF-395-505 (120 degree K at 50 dB of gain) to $1095. This is such a fast changing area of innovative pricing and production efficencies that if you are interested in investing someplace around $1000 or so in an LNA you are advised to check with the respective suppliers. The general trend is downward in pricing for all parts of the LNA picture however. If prices continue to tumble the point will eventually come where the economic incentive for building your own LNA will disappear.

As with the preamplifiers, the rest of the receiver is built using modular techniques. While this is not the way one would approach the design if quanity manufacture was being considered or compactness desired, it is ideal for single units or prototypes where it is desired to minimize interaction between stages and make troubleshooting, and experimenting as simple as possible. Connection between modules is done with small screw-on type coaxial connectors (SMA or OSM depending upon manufacturer, but interchangeable) and rigid coax. Beginning with the input to the final IF at 70 MHz the more common BNC connectors are used. The smaller connectors are used for both mechanical and electrical reasons in the microwave stages and BNC (or other low frequency connectors) type should not be used above 1 GHz.

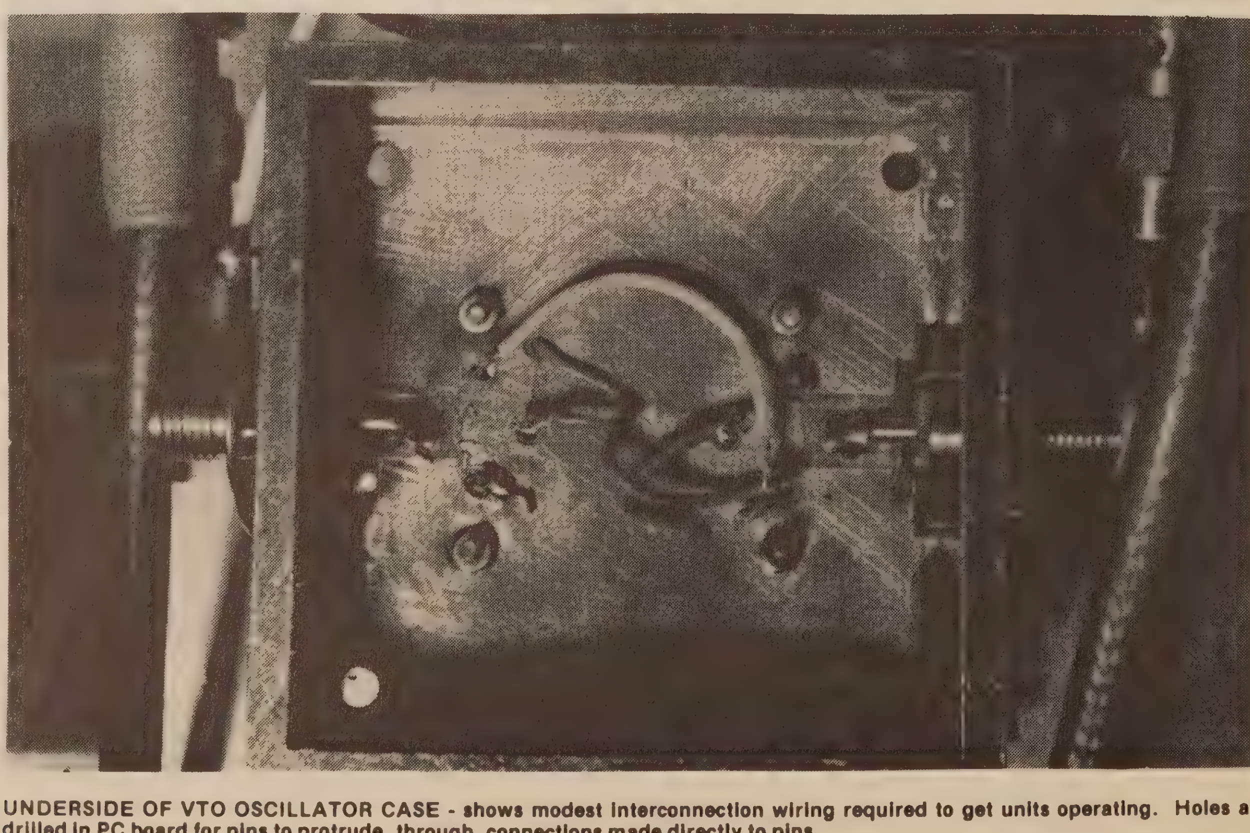
In the first proto-type receiver constructed, the mixer was a Watkins Johnson M1H which cost $199 at the time. The present system uses a recently announced and currently available mixer, the VARI-L DBM 500 ($75). Both work well, are properly packaged with



1200 MHz SECTION PLUS VCO'S - Avantek VTO series oscillators are to far right; 1200 MHz segments center and left. High and low mixers (DBM500) are center top and bottom.



AVANTEK VTO OSCILLATORS are housed in single container.



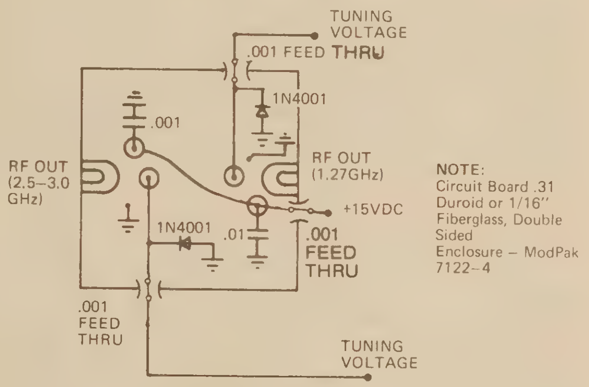
UNDERSIDE OF VTO OSCILLATOR CASE - shows modest interconnection wiring required to get units operating. Holes are drilled in PC board for pins to protrude through, connections made directly to pins.

the right connectors and duplication by the home builder would be difficult to impossible and certainly no cheaper. The mixer converts the broadband 3.7 to 4.2 GHz signal down to the first intermediate frequency (IF) of 1200 MHz.

The local oscillator which drives the mixer LO port is another high technology device and is the heart of the frequency agile receiver. It is a Voltage Tuned Oscillator (VTO) at a present cost of around $115 (and again, forecast to head down) which is controlled by a DC voltage between 1 and 15 volts to cover the necessary LO tuning range of 2.5 to 3.0 GHz. The voltage is roughly set with a tuning potentiometer and then is fine tuned in this circuit by an Automatic Frequency Control (AFC) derived from the discriminator or Phase Locked Loop (PLL). The Voltage Tuned Oscillator is available in a TO8 type can (package) with 4 leads and can be packaged on a circuit board as shown here. If you want to go the gold plated route, the manufacturer (Avantek) has a housing and a PC board available for about double the price of the VTO alone.

Next in the system is a 1200 MHz bandpass filter and a 12 dB gain amplifier stage at 1200 MHz. The original units in the Howard Terminal came from Microcomm (Paul Shuch at 14908 Sandy Lane, San Jose, Ca. 95124) but at the present time these modules are not being offered on the market. Microcomm has licensed a couple of manufacturers to produce satellite TV receivers utilizing the Microcomm modules and Paul Shuch has decided that for the time being he will not offer individual modules (i.e. less than a complete set) which might end up being in competition to those firms he has licensed for production of full receivers largely built around Microcomm modules.

HOWARD TERMINAL DUAL VTO



NOTE: VTO UNITS MOUNT ON OPPOSITE SIDE SHOWN, BOARD MUST BE DOUBLE SIDED

In light of these two items (the 1200 MHz bandpass filter and the 1200 MHz amplifier) no longer being readily available from Microcomm, there are the following alternatives:

1) The 1200 MHz bandpass filter was described by Paul Shuch in the December 1975 issue of HAM RADIO magazine (page 46). The construction details are complete and you should have no difficulty duplicating this work. HAM RADIO is Greenville, N.H. 03048.

2) The 1200 MHz amplifier can be built from another Shuch article appearing in HAM RADIO for October, 1975; page 42. However, in light of this non-availability the original premise that seemed to require the 12 dB of amplification at 1200 MHz was re-evaluated by Howard. The 12 dB of gain was originally designed into the circuit because 12 dB of gain here was less expensive than 10 to 12 dB of additional gain at 4 GHz. With changes in pricing on bi-polar transistors in the 4 GHz region, this may not be true any longer. If the system has between 40 and 50 dB of gain at 4 GHz (i.e. adding a fifth stage of gain in the LNA string) the reason for the 1200 MHz gain is gone. Therefore this stage, if it proves a problem for the builder, could be eliminated and replaced with another 4 GHz stage.

3) At least two firms are currently giving serious thought to producing either the 1200 MHz bandpass filter or the 1200 MHz amplifier; or both. We suggest you contact the following reference for these portions of the receiver:

1) Mr. Royden Freeland, International Crystal Mfg. Co., 10 North Lee, Oklahoma City, Oklahoma 73102

2) Mr. Jon Lieberg, LAB-TRONICS, Box 171, Rogers, Mn. 55374 (this firm also produces a line of MDS converter kits; see August 1979 issue of 73 magazine)

IF-DISCRIMINATOR SECTION

There are at least three options in the IF-discriminator section which should be discussed. In the present Howard Terminal, a 'surplus' solid state amplifier, filter and discriminator built by Lenkurt Electric 15 years ago for telephone service (remember that the terrestrial telephone trunk routes utilize the same 3.7 to 4.2 GHz frequency range, and that this fact produces a wealth of surplus equipment largely adaptable for TVRO work). The model number of the IF amplifiers, the filter and the discriminator are 28417, 28420 and 28418 respectively. The particular 'version' needed is the mod 5 which was intended for broadband video usage. If you can only locate the mod 2 thru mod 4 versions there are minor changes required and Taylor Howard will supply same to anyone needing them. The second option open is the TL 2 (solid state version of the TD 2) IF to baseband unit used in TELCO microwave links. Such units are difficult to find because of the sudden popularity of the TD 2 family modules for conversion purposes to low cost TVRO terminal work (see 'COLEMAN TD 2 CONVERSION MANUAL', also available from Satellite Television Technology) but if you are lucky it may be suitable. Both the Lenkurt and the TL 2 units use a 70 MHz IF and produce baseband video (plus subcarrier audio) and an AFC output.

A third alternative is to build your own IF gain and bandpass filtering and then recover the video using a phase locked loop (PLL). Let's tackle the gain portion first. You need about 40 dB of gain centered on 70 MHz. If you have access to CATV (cable television) equipment, you will find that any number of CATV modules have exactly what you want already operating and the price may be very low. For example, any BLONDER TONGUE model MCS-4 strip amplifier (a tube type 40-50 dB gain TV channel amplifier centered on TV channel 4 - 66 to 72 MHz - but easily re-aligned to cover 60 to 80 MHz) will do the trick. Other versions by Jerrold, ENTRON or AMECO will also work. You are looking for 40 to 50 dB of gain, remember, and the ability to re-align the unit over the 60 to 80 MHz region. A current model device, the BLONDER TONGUE MCA-4 will also do the job although it's solid state price tag will be near $175 (for information contact DAVCO, P.O. Box 861, Batesville, Arkansas 72501; they may also help you locate the older tube type units). Then there are CATV 'line amplifiers'; solid state devices which typically have 25 to 30 dB of gain over a wide frequency spectrum (typically 50 to 220 MHz or more). Two of these in cascade will produce the gain you require and many CATV companies 'scrap' amplifier module plates when they upgrade their cable plants to wider spectrum coverage. You'll need two to reach the 40 to 50 dB gain block requirement however.

If you set out to build your own 40 to 50 dB of gain centered on 70 MHz, one of the easiest ways to do this is to use Avantek amplifier modules. The GPD series type 401, 401, 402 and 403 in series offer a simple and effective way using self contained amplifier modules in TO-8 type cans to cascade the gain you need on a simple PC board, or using housings available from Avantek. Avantek has a manual entitled 'Designing with GPD Amplifiers' available; see their address in reference section. Howard recently built up a 40 dB (+) string using the Avantek 401, 401, 402 and 403 and reports it operates perfectly with no problems.

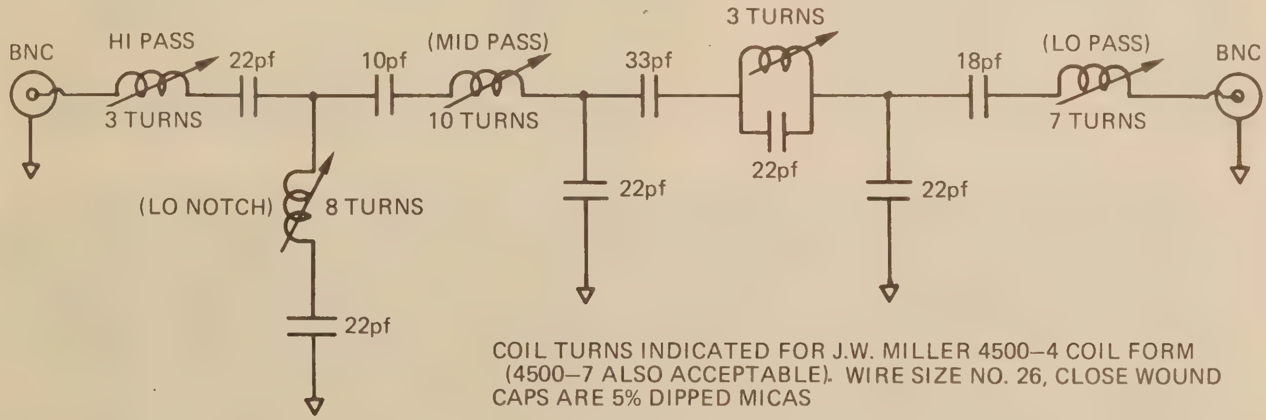
The basic thing to remember when selecting the IF gain block system is that you need better than 0.5 dB of ripple (i.e. less than a half a dB) from 55 to 85 MHz and enough

gain (typically 40 to 50 dB) to provide at least 100 millivolts (-7 dBm) to the PLL input.

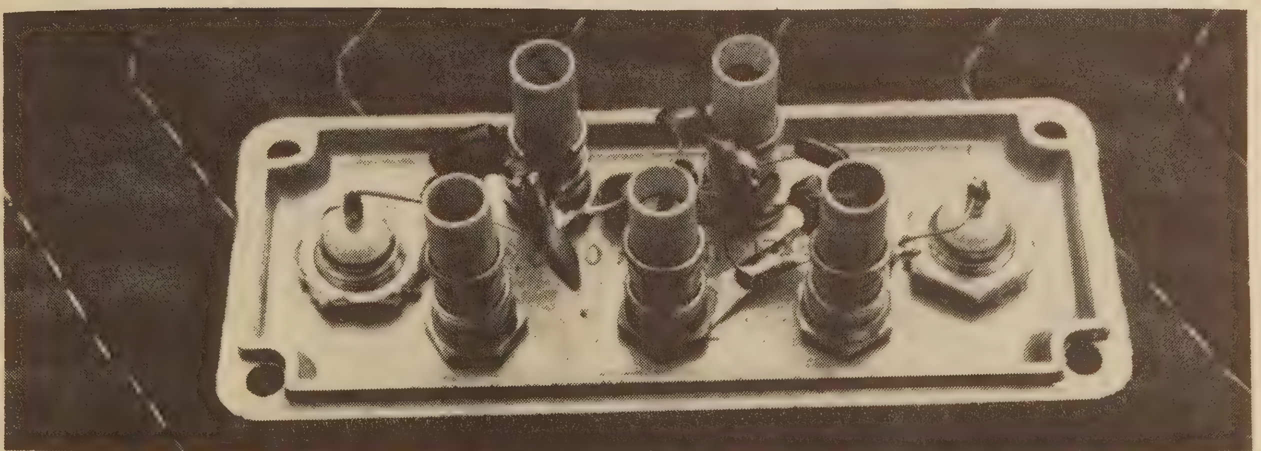
The IF amplifier you find, buy or build may well have gain beyond the frequency spectrum required (55 to 85 MHz). Even if you build it yourself, it is very important that you have a 'shaped passband' in the 70 MHz system to insure that adjacent transponders received from the satellite do not interfere with your desired transponder reception. This is best handled by building the passband filter shown here which is designed around commonly available parts. You will probably need to align this on a sweep system (sweep generator, markers and a detector probe with scope display). CATV firms have this type of bench test equipment and with it to work with you should be able to align the five adjustable slugs in around five to ten minutes time. The only real parameters to align to are:

1) Keep the passband flat to within 0.5 dB from 55 to 85 MHz (or 60 to 80 if you are going for a 20 MHz wide IF);

HOWARD TERMINAL 70 MHz BANDPASS FILTER (30 mHz 3 db BANDWIDTH)
LOSS <1.5 db, RIPPLE ±0.5 db

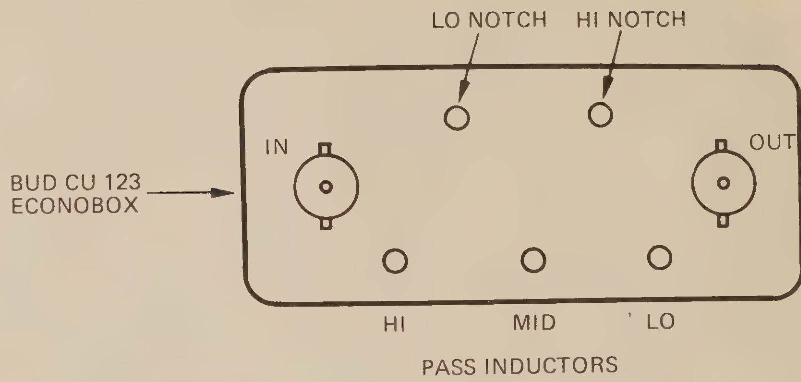


COIL TURNS INDICATED FOR J.W. MILLER 4500–4 COIL FORM (4500–7 ALSO ACCEPTABLE). WIRE SIZE NO. 26, CLOSE WOUND CAPS ARE 5% DIPPED MICAS

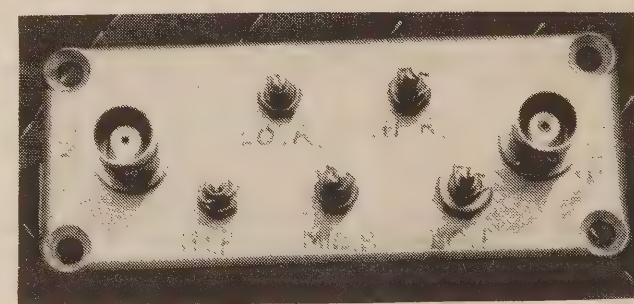


70 MHZ (center frequency) i.f. filter uses commonly found coil forms and stright forward approach to create desired i.f. passband system.

2) Loss (as measured with the sweep alignment system) through the 70 MHz band-pass filter should be as low as possible and in no case should it exceed 3 dB. (If it checks higher than this you have an alignment or construction problem.)

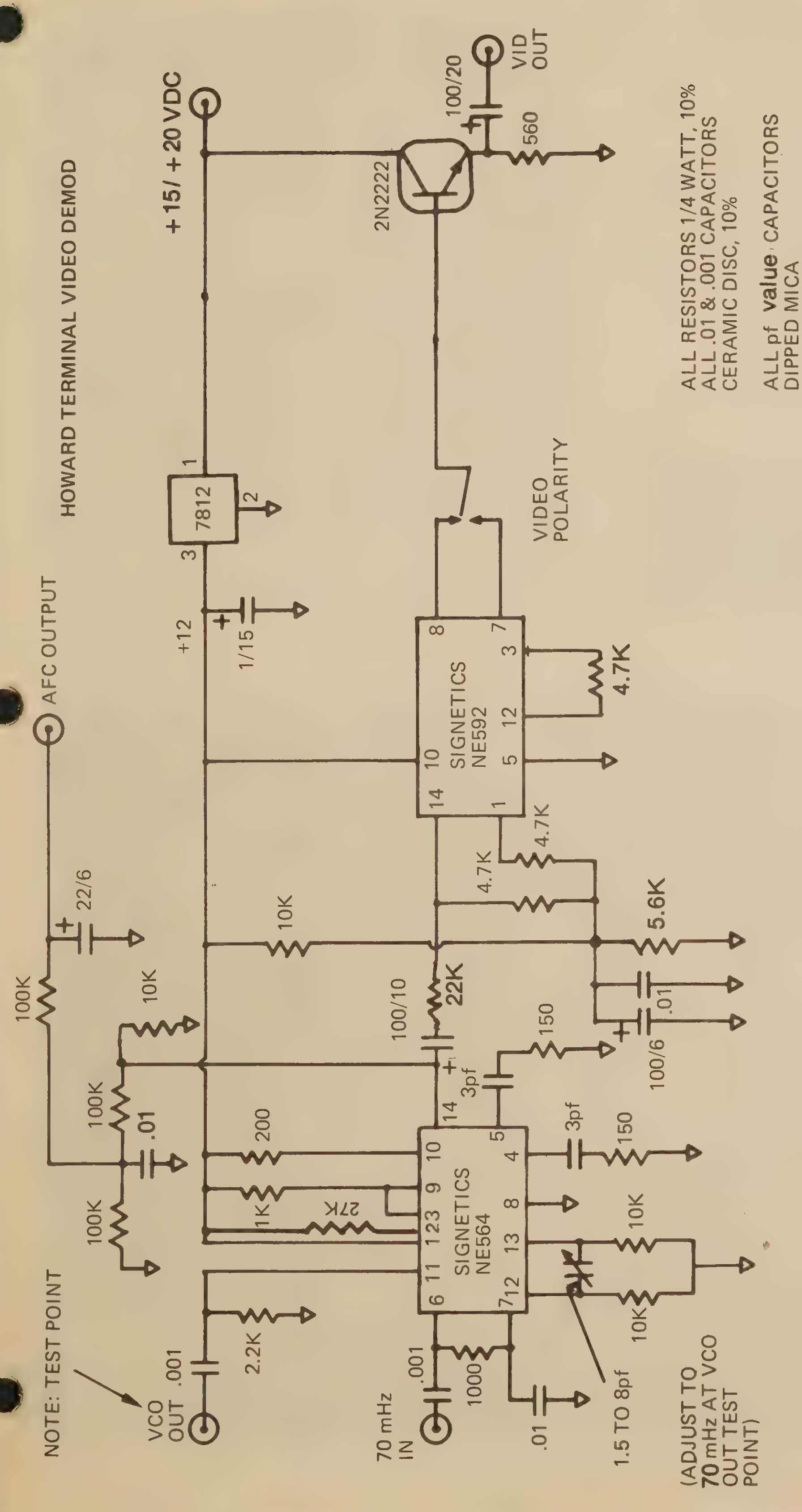


The alignment adjustments should be done with the cover in place.



The PLL discriminator shown here works very well; as well or better than the commercial units. It is built on a double sided PC board, installed in a shielded box and then mounted on a piece of aluminum for insertion into the card cage. The shielding is required to keep

FULL HOWARD TERMINAL RECEIVER - uses Douglas 'card cage' to hold individual modules. Foreground controls are for azimuth and elevation control of dish, and channel changing.



the PLL from interfering with TV channel 4 (the PLL is centered at 70 MHz which is within TV channel 4). If you are planning to use channel 4 as your VHF output channel, this is especially important!

The PLL can be set to the proper frequency with a frequency counter or simply tuned for best looking picture.

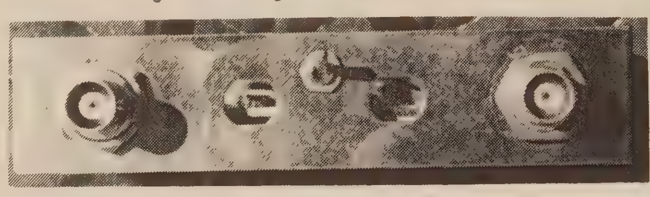
THE AFC

Frequency control of the system is determined by two oscillators. The second conversion oscillator, which is fixed (at 1,270 MHz) is either the Avantek VTO 8090 or some suitable replacement (Microcomm did make such a unit and offer it on the market for a period of time). The first oscillator (tuning 2.5 to 3.0 GHz) is tuned by two voltages; coarse tuning by a potentiometer and fine tuning by an AFC system shown on page 21 here. If the two VCOs (VTO devices) are placed together in a reasonably temperature stable environment their drifts tend to cancel (one is a high side mix and one is a low side mix). In this situation the system can run for hours with no AFC and no tuning.

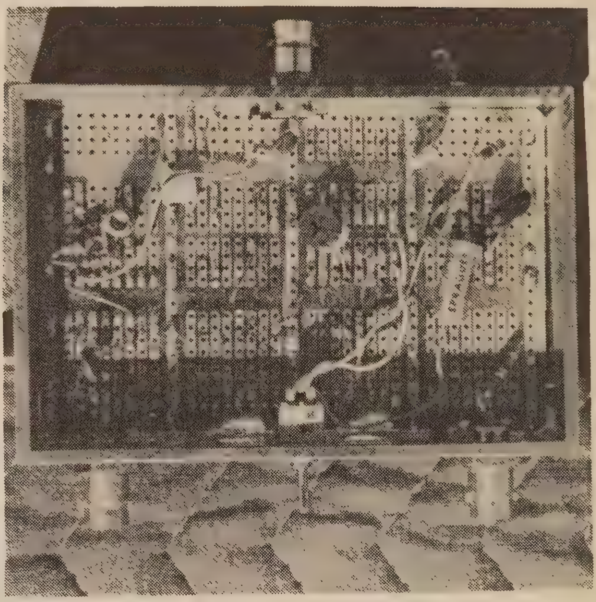
As an aside, noise in an FM TV system has the same characteristics of any FM system once you translate voltage polarity to picture polarity; i.e. when you are tuned to 'one side' of the proper (LO) frequency the noise impulses are white and when you are tuned to the other side the noise impulses are black. Thus, one tunes for 'equal amounts of salt and pepper' in a marginal system and in between for a good system. The AFC eliminates the need for great care in this tuning, for

one simply defeats the AFC, tunes for 'in between', and snaps the AFC back on.

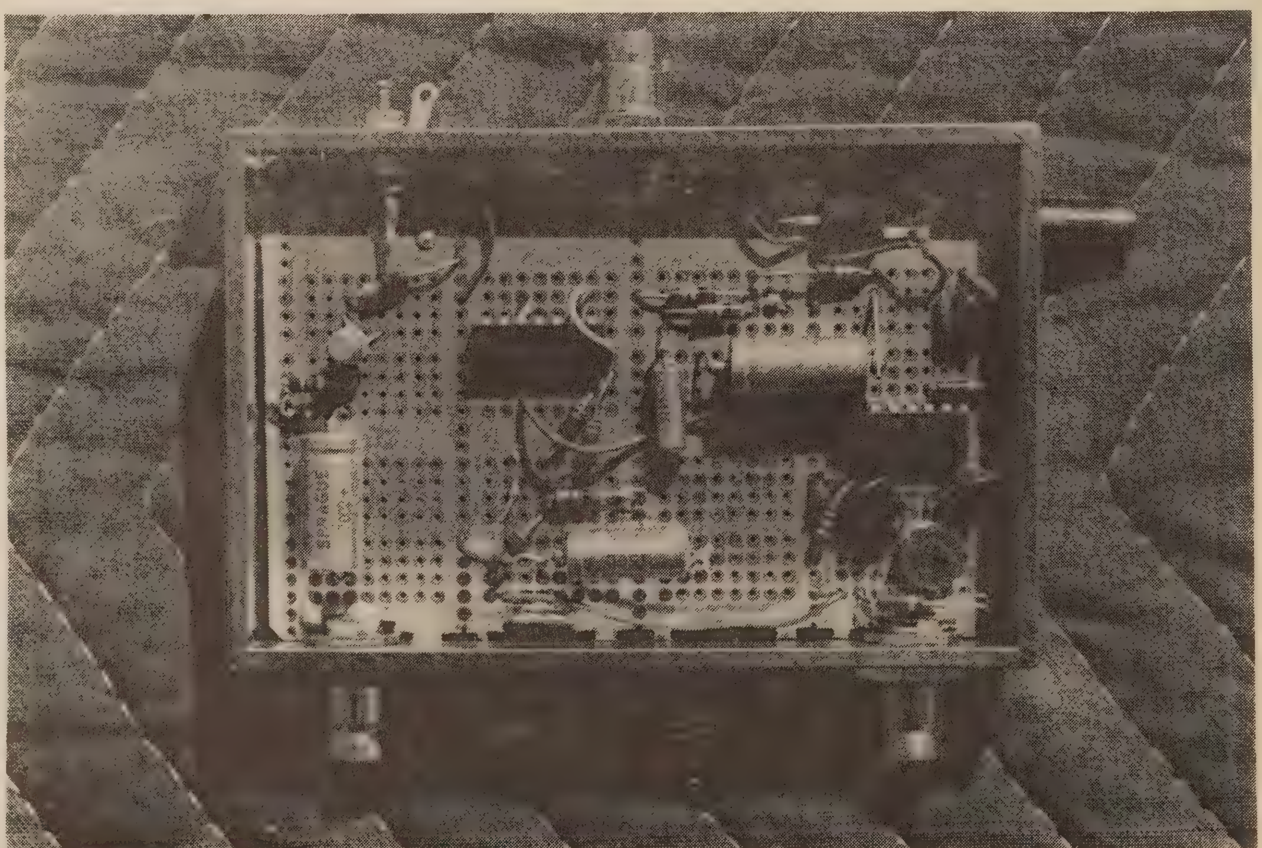
Once the signal has been discriminated or PLLed the baseband video should now be recognizeable for what it is except for the fact that the sync tips will be going up and down at a 30 Hz rate due to the energy dispersal waveform. This is handled by a portion of the circuit between the HEP 3011 stages on the 'Video Stages' circuit diagram. This (HP5082) diode acts as a clamp on the sync tips and effectively destroys the 30 Hz wave-



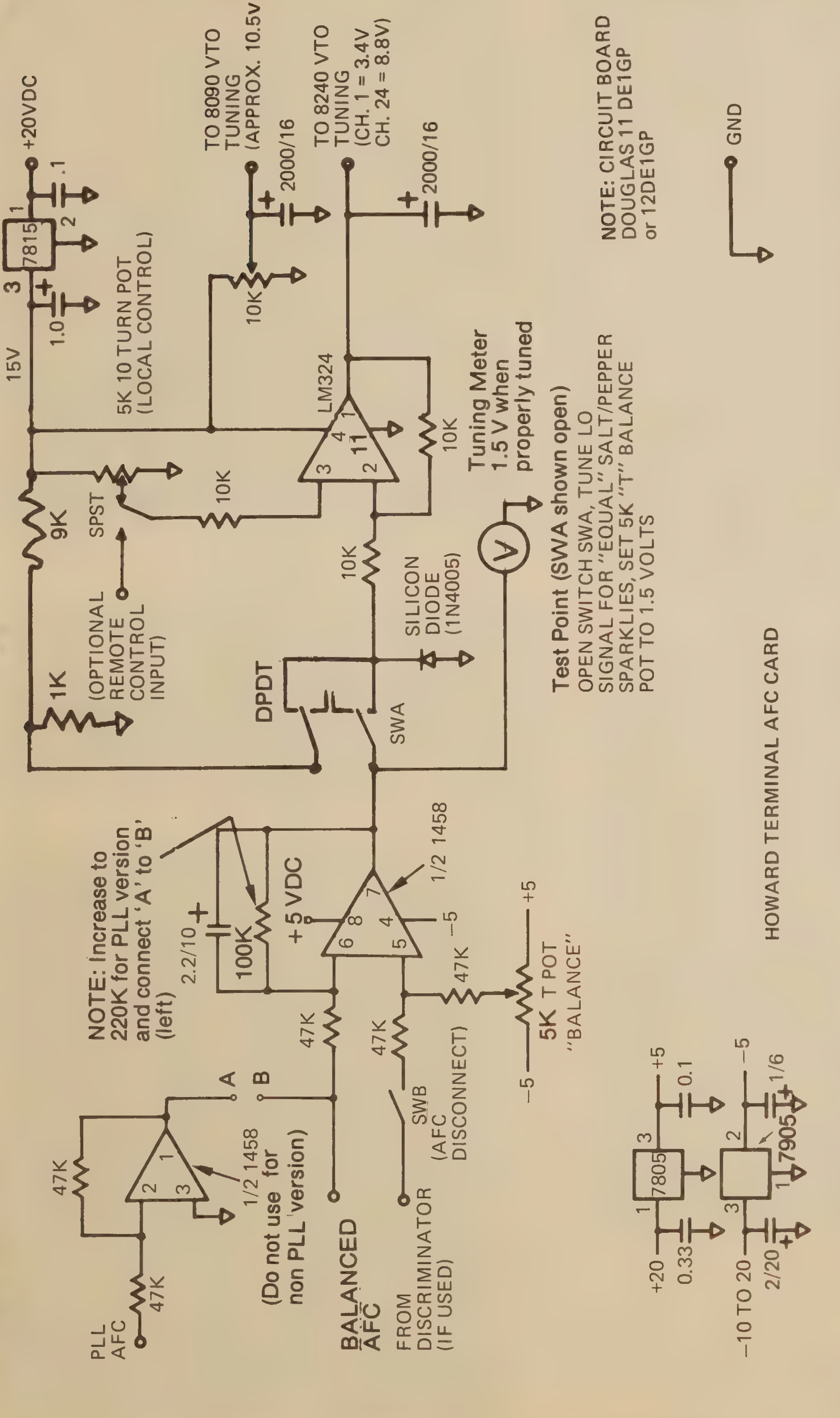
FRONT PANEL of PLLsection.



PLL - bottom side of circuit board and container.



PHASE LOCK LOOP UNIT - demodulator for the Howard Terminal.



HOWARD TERMINAL AFC CARD

form.

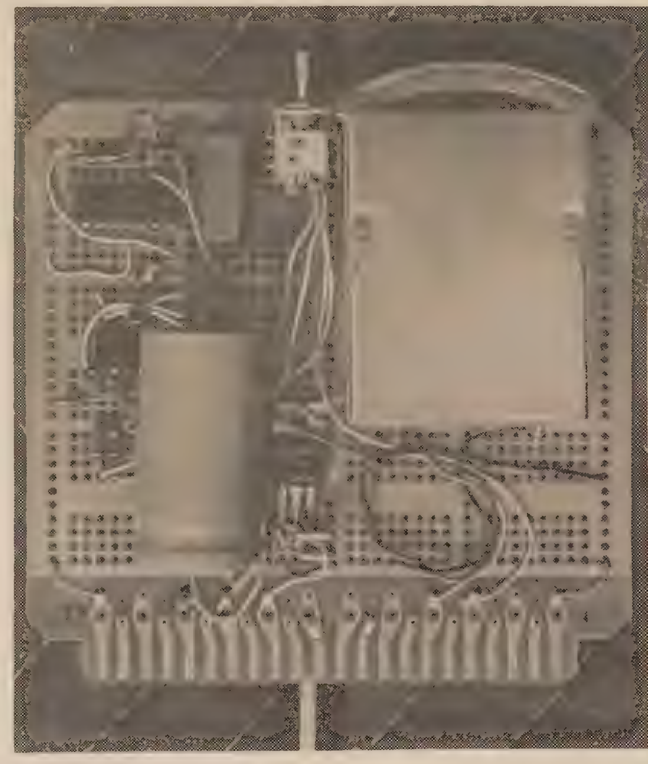
In this circuit (found on page 23) we have video gain, the standard CCIR de-emphasis filter, a 4.5 MHz low pass filter and an emitter follower. The components in these filters are dipped mica capacitors and the small ferrite RF chokes. Standard values have been used to make duplication of the working circuits easier for the builder although the true videophile may wish to tweek and play to fine tune these 'broadcast-quality' determining networks.

A word here about the detail for alignment and layout. The photos here show the general layout; Douglas boards and a plug in cage system was utilized by Howard for his receiver. The only critical or 'do-as Howard-did' layouts are shown. The microwave portion are detailed, the 70 MHz and below segments are shown with considerable schematic detail.

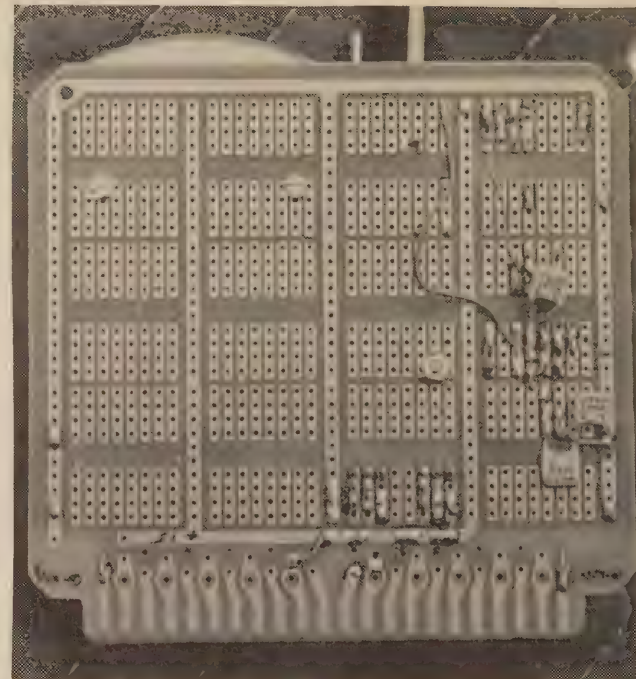
Anything above 'baseband' requires short leads and reasonably good layout practice. Where shielding or other problems exist, this manual so states. Otherwise it is assumed you have some experience as a builder can layout nice effective boards given the parameters and a working schematic and can understand the basics of what is happening in each section.

Parts values should be followed unless you are prepared to do your own debugging and troubleshooting!

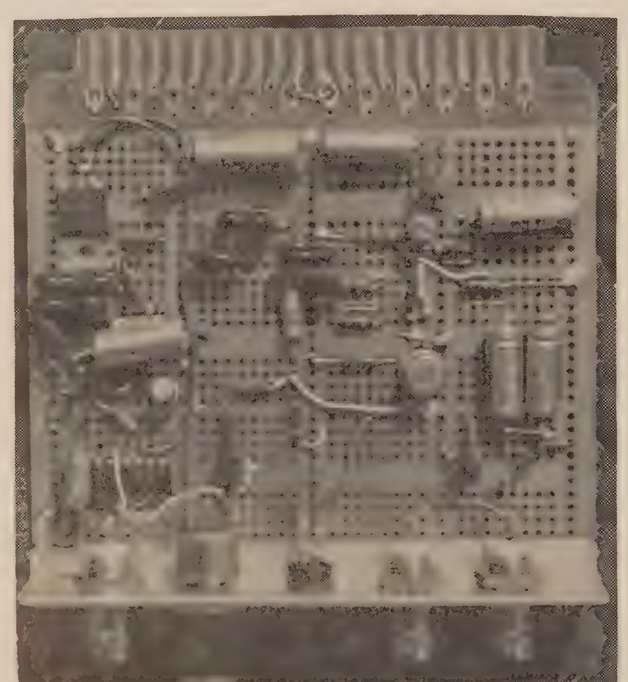
howard terminal



AFC CARD - voltmeter is apparent top right.

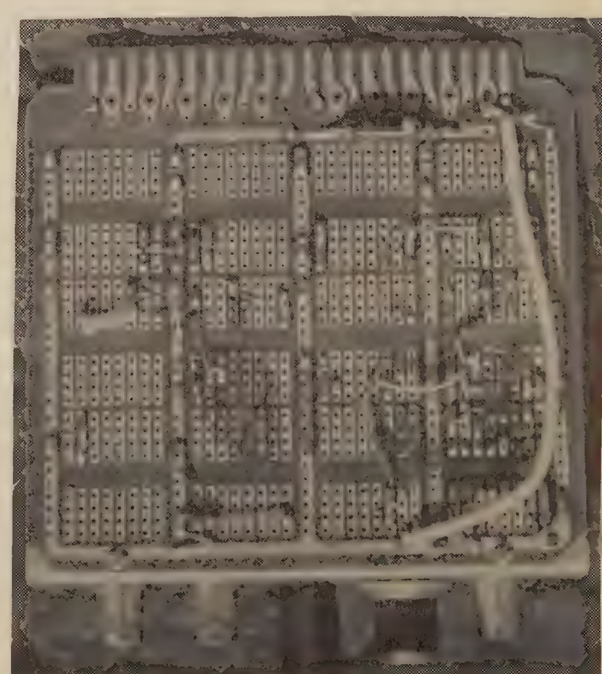


AFC CARD - underside of card section.



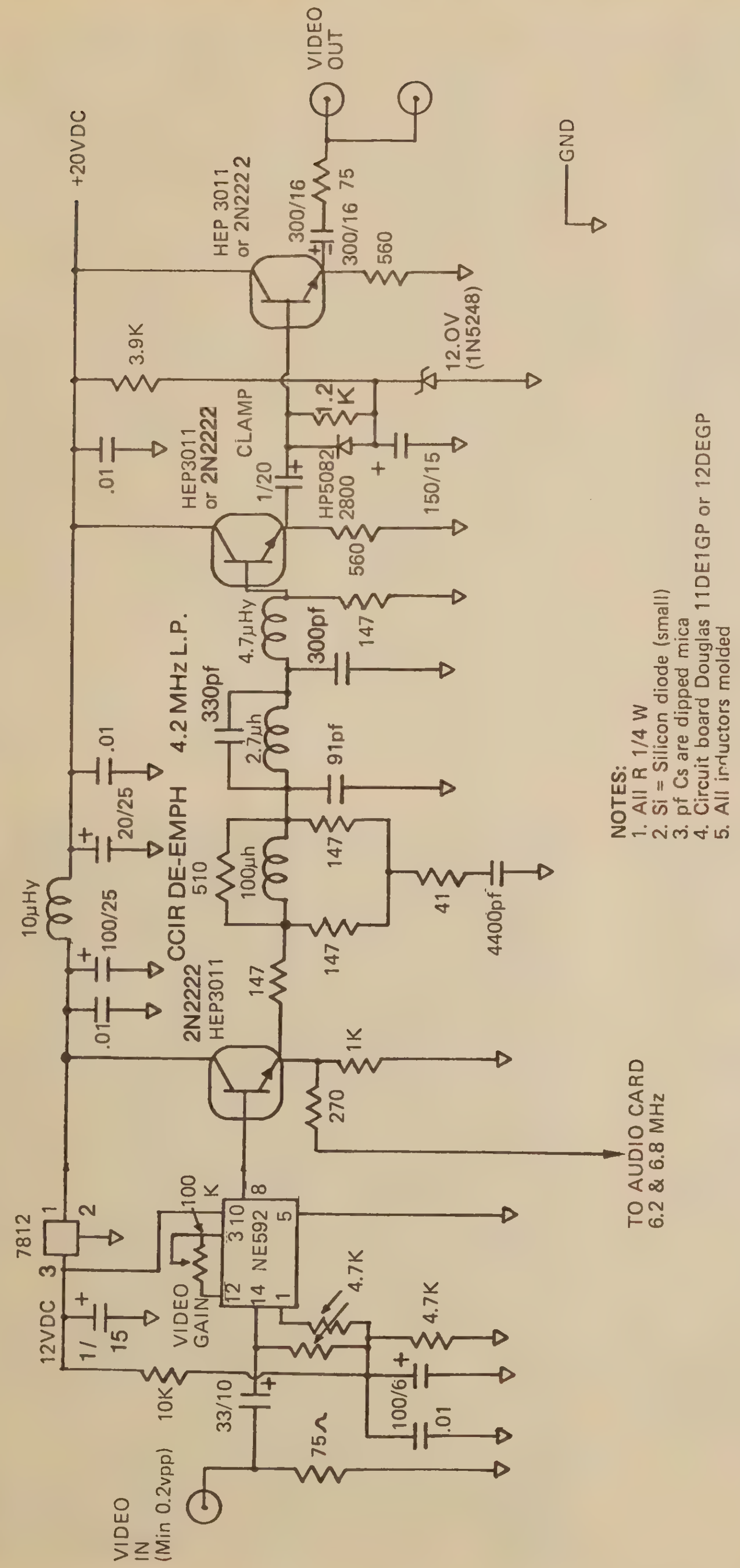
VIDEO AMPLIFIER - filters and clamp circuit board.

END ON - model for VIDEO MODULATOR.



VIDEO MODULATOR - circuit board bottom side.

HOWARD TERMINAL VIDEO STAGES



RECOVERING AUDIO

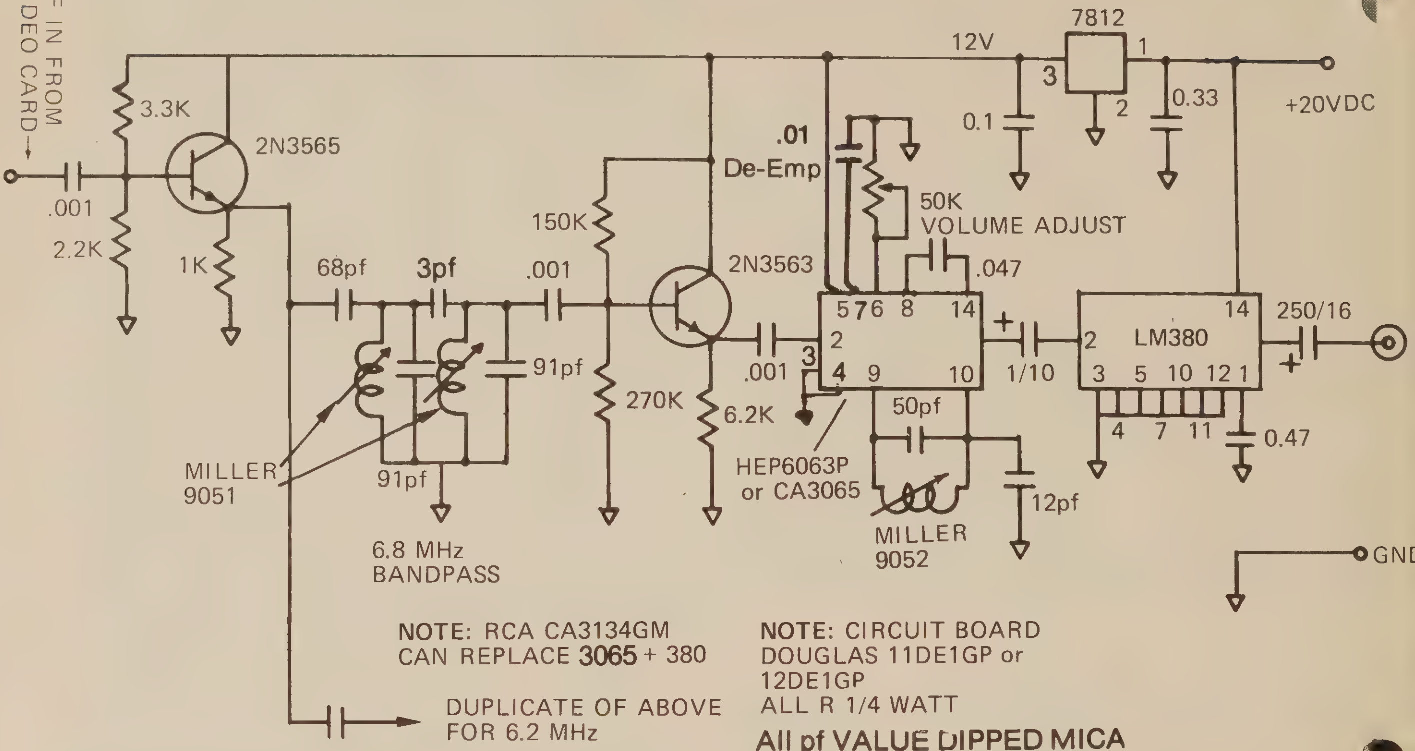
The audio signal is removed from the Video Stages card by an emitter follower which drives two different bandpass filters and an audio recovery section(s). Note on the Video Stages card schematic that we have a pair of output jacks ('Video Out'). One of these will go to the video modulator while the second is a spare output. Note that the audio signal is recovered from the appropriate (frequency) subcarrier; 6.8 MHz is the most common used, especially on RCA SATCOM FI. The Miller 9051 coil forms are tuned to pass the (6.8 MHz) subcarrier and the Miller 9052 tunes for recovery of the audio. You can do this by ear or get sophisticated and use a 6.8 MHz signal generator with a tone modulator. When Howard designed his system IC parts available at reasonable prices dictated that he use the HEP6063P to recover the audio and the LM380 to amplify it. Now the RCA CA3134GM is available to do both jobs in a single device.

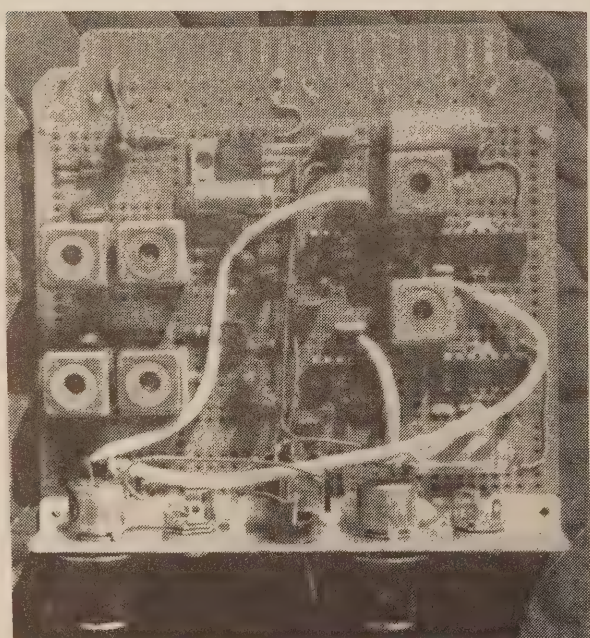
If you are going to equip your terminal to have 'switch selectable audio' (i.e. either 6.8 or 6.2 MHz), you duplicate the Audio Card portion after the emitter follower for the second (etc.) audio subcarrier frequency. The parts values stay the same; you simply tune it up to a different subcarrier. Note that RCA is now experimenting with digital audio on 5.5 MHz and on SATCOM F1, transponder 6, UPI runs part of their slow scan TV 'Newstime' news pictures on 7.4 MHz (with the balance on 6.2; yes transponder six's subcarriers are filled up!).

WATCHING IT

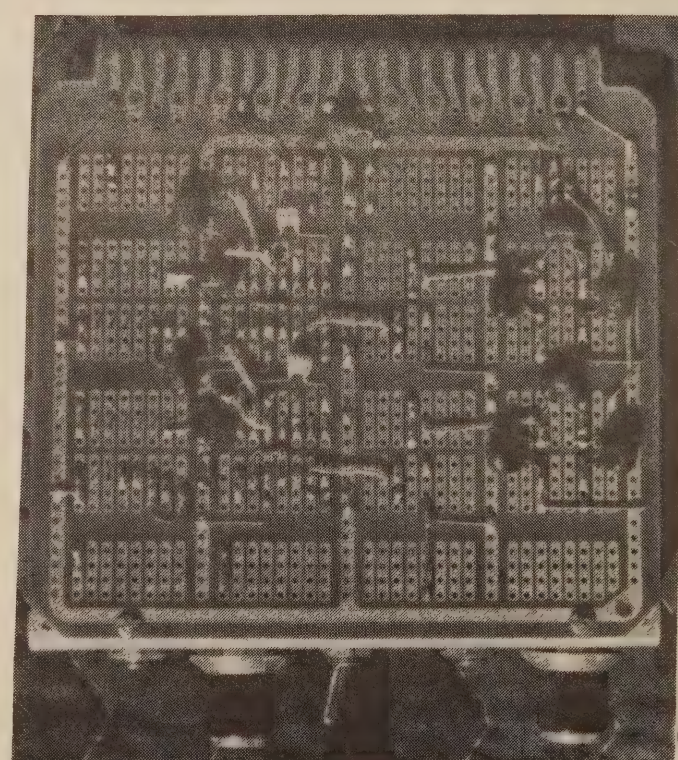
You are now very close to being

HOWARD TERMINAL AUDIO CARD



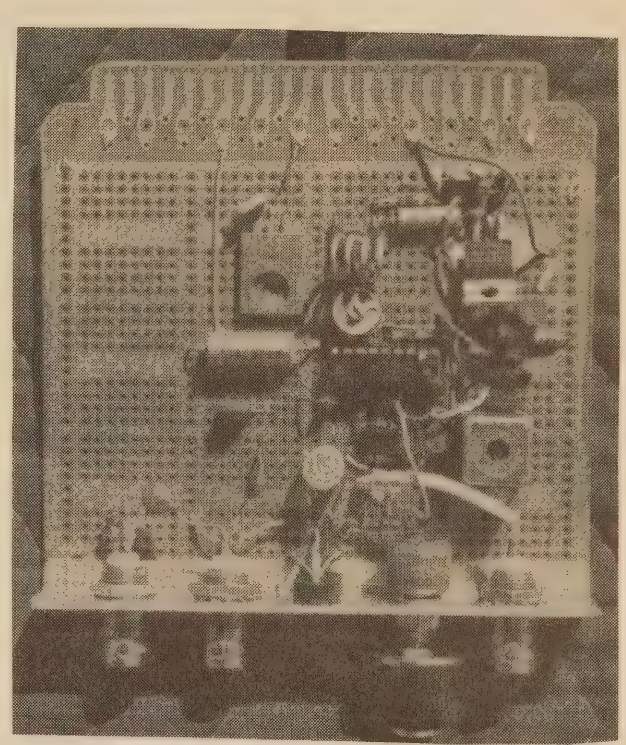


AUDIO CARD - Howard Terminal.



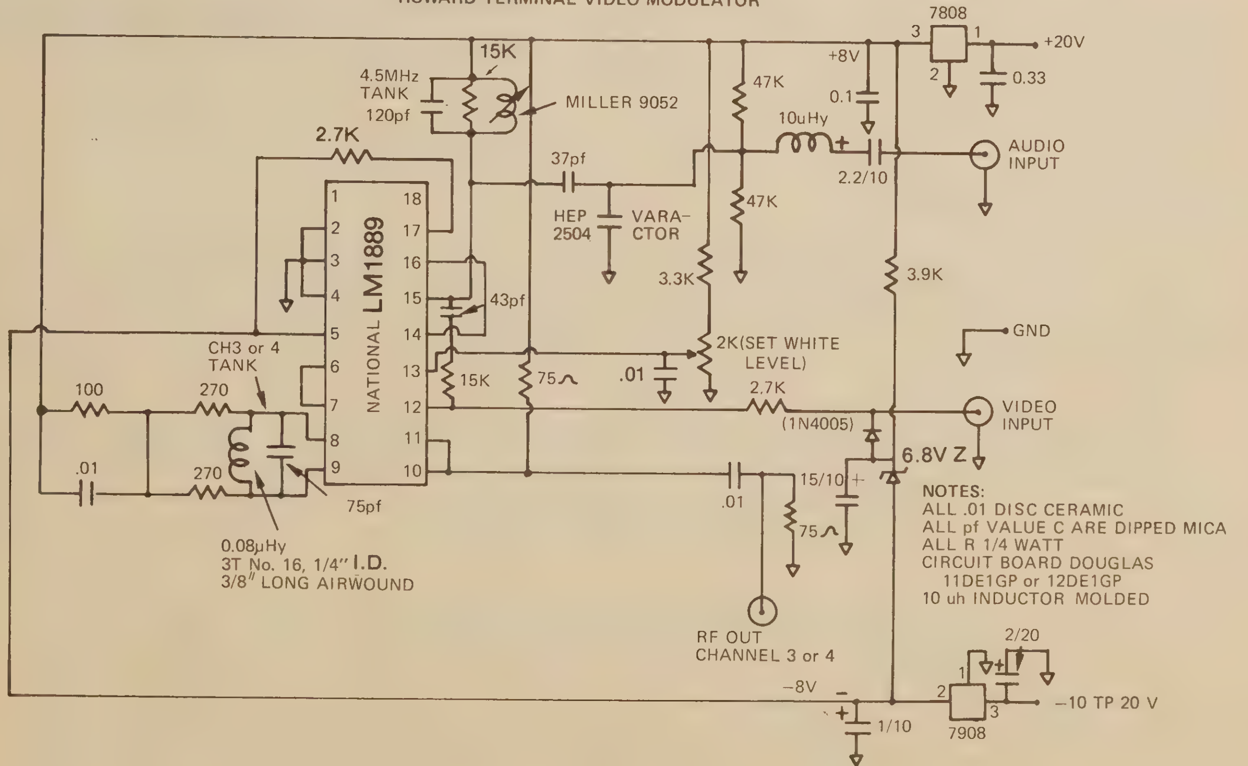
Bottom side of audio card.

able to watch and listen to the satellite TV signals. The video and audio output(s) from the Video Stage(s) and Audio Cards respectively can be used to directly drive a (color) monitor; and, or, the video modulator shown here. This video modulator consists of a single National Semiconductor LM 1889 which is used in many (home) video games. The output is tuneable to either TV channel 3 or 4 (and some report it will go to channel 5 as well) for standard U.S. television format RF. The quality is excellent. The LM 1889 is available from many parts distributors (such as Poly Paks which advertises in everything from POPULAR ELECTRONICS to 73) for usually under $5. Please note that channel 3 is 60 to 66 MHz (video is on 61.25 and audio on 65.75 MHz) and channel 4 covers 66 to 72 MHz (video 67.25 and audio on 71.75 MHz) so one must adequately shield and bypass IF and PLL circuits operating in this frequency range (typically 55 to 85 MHz with a 30 MHz wide IF centered on 70 MHz) to prevent interference in your RF output signal.



RF MODULATOR - takes video input and produces channel 3 or 4 RF output for viewing on standard NTSC television receiver.

HOWARD TERMINAL VIDEO MODULATOR

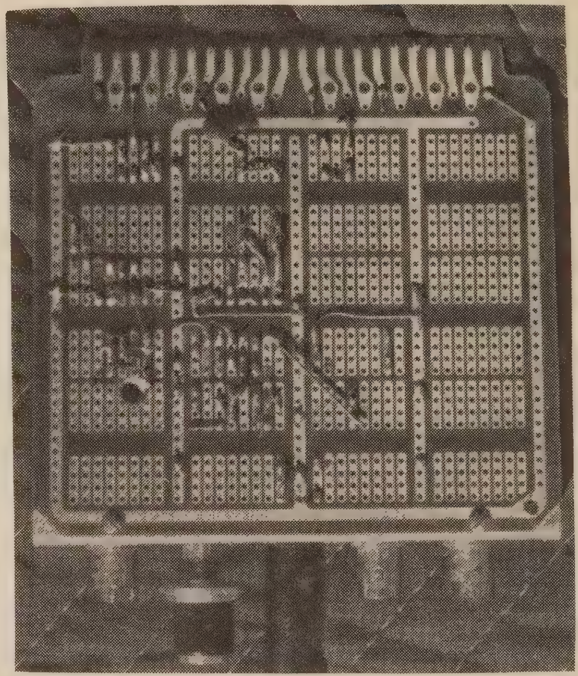


A complete RF modulator kit using the LM 1889 is available for $24.50 from ATV Research (model PXP 4500 / Pixieplexer) at 13-B Broadway, Dakota City, Nb. 68731.

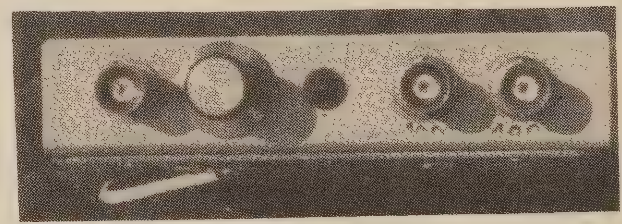
CONSTRUCTION TIPS

Once out of the discriminator or PLL, construction techniques are straight forward and reference to the photos should make layout a simple task. Be sure to use double sided PC board (i.e. one having a solid ground plane) with the wiring on one side. Isolate the various boards using on-board regulators (as shown in the schematics), bypass capacitors and chokes; plus shielded interconnecting cables with the shield to the ground plane 'ground'.

Taylor Howard utilized Douglas boards and plug-in cages for construction. These are more expensive than other approaches, but they provide the grounding integrity, and the ground planes necessary for stable success. A PC layout for each board would not be a complicated chore but for only a few of a board, or one-each for a single receiver, it hardly seems like it is worth the time required. Experience with nice, neat, PC board layouts is that the first layout will oscillate, or won't work at all or all of the above and Howard felt in designing the system life was too short to spend it debugging a PC board layout!



RF MODULATOR - underside of circuit board.



FRONT PANEL - RF modulator board. Jack to left is video in; control is white-level-set. Jacks to right are RF (modulated) output.

PLOTTING SYSTEM PERFORMANCE

Once you have a working system, how do you tell how well it is working? The pictures received are of course some indication of performance but this technique fails to give you the assurance that the system is really working within the last half dB of its capabilities. It would be desireable to independently evaluate the noise temperature performance of the system.

This can be done quite simply by aiming the antenna at the sun and observing the rise in background noise by suitable metering of the 70 MHz IF prior to the hard limiting stages. A step attenuator is then adjusted to move the meter reading back off to off-sun value of noise. One then calculates the system actual G/T by using the following formula:

$$G/T = 10 \text{ Log } \frac{10 \text{ Log (dB increase)} - 1}{0.130} \text{ dB/degree K}$$

The theoretical G/T for comparison is:

$$G/T = 10 \text{ Log } \frac{\text{Antenna Gain}}{\text{System Noise Temp}} \text{ dB/degree K}$$

For example, the G/T for a 15 foot antenna (43 dB gain = 20,000) with a 300 degree system temperature is:

$$G/T = 10 \text{ Log } \frac{20{,}000}{300} = 18.24 \text{ dB/degree K}$$

For a system which 'sees' (i.e. measures) an 11 dB increase in background noise when aimed at the sun, the actual G/T is:

$$G/T = 10 \text{ Log } \frac{10 \text{ Log } 11 - 1}{0.130} = 18.6 \text{ dB/degree K}$$

Assuming antenna gain of 20,000 one can use this to calculate a system noise temperature of 276 degrees Kelvin. For a complete explanation of this technique using any radio source the reader should locate Microwave Journal for April 1977 (vol. 20, No. 4), page 49 (51,58) for "Satellite Earth Terminal G/T Measurements" by D.F. Wait. For the above calculations a solar flux of 8×10^{-21} w/m^2/Hz was utilized.

There are several caveats associated with pointing an antenna into the Sun. If you are utilizing a screen mesh reflector, you need not be concerned about heat build up at the focal point from reflected solar energy. However for a solid metal surface dish solar ray focusing can be a disaster. Satellite antennas are painted with a special light-ray scattering white paint to 'scatter' the focused energy harmlessly off of the RF focal point. Lacking that, a brightly 'polished' aluminum reflector surface can produce focused solar heat in excess of several thousand degrees C. Since the solar heat will focus at the same point as the 4 GHz energy, your feed horn may 'unsolder' itself and your LNA explode in a burst of flame under such conditions. It actually happened to one experimenter!

Therefore use care when pointing into the sun. Even a coat of flat white paint (without the special light scattering parameters) will cut solar focusing sufficently to prevent excess solar heating during short tests.

The sun will align with the satellite during two periods of the year without any help from you. During the spring and fall equinox season, for a period of a couple of days, typically late in the afternoon for most U.S. locations, the sun lines up behind the satellite and you can 'measure' the solar noise as the star 'drifts' by the antenna. During these brief (from start to finish typically under 20 minutes) periods satellite reception deteriorates as the solar 'noise' covers up the satellite RF signal.

Finally, during the present peak of the sun spot cycle it may be that you will measure excess amounts of solar noise if your testing coincides with solar eruptions. For this reason it is adviseable to check WWV for the propagation forecast (18 minutes past the hour) to insure that solar conditions are 'normal' or 'quiet' before making the measurement.

SUPPLIER LIST

Mixers - VARI-L Company, Inc., 3883 Monaco Pkwy, Denver, Co. 80297

VTOs - Avantek, 3175 Bowers Ave., Santa Clara, Ca. 95051 (minimum order $100)
Note: Avantek is handled by many distributors; list is available from Avantek.

Microwave Transistors - Hewlett Packard, 640 Page Mill Rd., Palo Alto, Ca. 94304
Note: HP has regional sales offices and a list of same is available from firm; for orders of 50 or more devices, deal directly with HP Palo Alto.

Microwave Chip Capacitors - Dielectric Laboratories, 69 Albany St., Cazenovia, N.Y. 13035 (Sales Rep: Kipp Associates, 4388 Alpine Rd., Portola Valley, Ca. 94025)
Microwave Chassis Boxes - MODPAK, 31 A Green St., Waltham, Ma. 02154 (Sales Rep: Wright Engineering, 175 S. San Antonio St., Los Altos, Ca. 94022)
Teflon Circuit Board (RT Duroid) - Rogers Corporation, Box 700, Chandler, Az. 85224 (Grade D-5880 226-127; thickness 0.031 Diel, Clad 1 oz. 2 sides)
PLL, IF Amps - Signetics Corp., P.O. Box 9052, Sunnyvale, Ca. 94086
Microwave Assemblies - Microcomm, 14908 Sandy Lane, San Jose, Ca. 95124 (see text)
Circuit Boards & Cages - Douglas Electronics, 713 Marina Blvd., San Leandro, Ca. 95477
Vector Electronics (at most distributors)

Selected HP/Avantek/Signetic Distributors or Representatives:

Alabama - Hallmark Electronics, 4739 Commercial Drive, Huntsville 35805 (205)837-8700 Handles HP, Avantek
Hamilton/Avnet (205)533-1170 Handles Signetics
Arizona - Liberty Electronics, 3130 N. 27th, Phoenix 85017 (602)257-1272 Handles HP
Thorson Company, 2505 E. Thomas, Phoenix 85016 (602)956-5300 Handles Avantek
Hamilton/Avnet (602)275-7851 Handles Signetics
California -
Liberty Electronics, 124 Maryland St.,El Segundo 90245 (213)322-8100 Handles HP, Signetics
Elmar Electronics, 2288 Charleston Rd., Mt. View 94040 (415)961-3611 Handles HP, Signetics
Cain Technology, 522 S. Sepulveda, Suite 112, Los Angeles 90049 (213)476-2251 Handles Avantek
Colorado -Elmar Electronics, 6777 E. 50th Av., Denver 80222 (303)287-9611 Handles HP
Thorson Company,5290 Yale Cr., Denver 80222 (303)759-0809 Handles Avantek
Hamilton/Avnet (303)534-1212 Handles Signetics
Connecticut -
Schweber Electronics,Finance Dr., Commerce Ind. Pk., Danbury 06810 (203)792-3500 Handles HP, Signetics
Florida - Hall-Mark Electronics, 7233 Lake Ellenor Dr., Orlando 32809 (305)855-4020 Handles HP
Beacon Electronic Assoc., 6842 NW 20th, Ft. Lauderdale 33309 (305)971-7320 Handles Avantek
Hammond Electronics (305)241-6601 Handles Signetics
Illinois- Hall-Mark Electronics,180 Crossen, Elk Grove Village 60007 (312)593-2740 Handles HP
Dy Tec/Central Inc., 121 S. Wilke Rd., Suite 102, Arlington Hgts. 60005 Handles Avantek
Schweber Electronics (312)593-2740 Handles Signetics
Maryland- Hallmark Electronics,6655 Amberton Rd., Baltimore 21227 (301)796-9300 Handles HP
Applied Eng. Consult.,9051 Baltimore Nat. Pk., Bldg. 3, Off. A, Ellicott City (301)465-1272 Handles Avantek
Schweber Electronics (301)991-2970 Handles Signetics
North Carolina -
Hall-Mark Electronics,3800 Industrial Dr., Raleigh 27609 (919)832-4465 Handles HP
Texas - Hall-Mark Electronics,9333 Forest Ln., Dallas 75231 (214)231-5101 Handles HP
Hamilton/Avnet (214)661-8661 Handles Signetics
Washington -
Liberty Electronics,5305 Second Av. S., Seattle 98108 (206)763-8200 Handles HP, Signetics

HOWARD TERMINAL POWER SUPPLY REQUIREMENTS

LNA — 1) +15 VDC
A) CURRENT PER STAGE - 4 mA

VTO 8240 — 1) +15 VDC OPERATING
(HIGH LO) (TUNING VOLTAGE + 3.4 VDC [CH. 1]
TO +8.8 VDC [CH. 24]

VTO 8090 — 1) +15 VDC OPERATING
(LOW LO) (TUNING VOLTAGE + 10.5 VDC APPROX.)

PLL — 1) +20 VDC

AFC CARD — 1) +20 VDC
2) −10 TO 20 VDC

VIDEO STAGES — 1) +20 VDC

AUDIO STAGES — 1) +20 VDC

VIDEO MODULATOR — 1) +20 VDC
2) −10 TO 20 VDC

TOTAL CURRENT REQUIREMENTS: POSITIVE / 500mA
NEGATIVE / 80 mA

NOTICE TO HOWARD TERMINAL USERS:

While this Manual is intended to be a complete guide to designing and building your own 'HOWARD TVRO TERMINAL' it is likely that some users of this Manual will have additional 'questions'. H.T. Howard, the designer and developer of this TVRO terminal is willing to answer your questions on an advisory or 'Consulting Basis'. Complete this form and return it with a check for $25 (made out to H.T. HOWARD) to the address below. This will place you into the Howard 'cónsulting file' through which you may write to request additional information, answers to questions and to ask advice.

Attention: Mr. Henry T. Howard / P.O. Box 6401, Stanford, Ca. 94305

I wish to sign up for your 'letter advisory/consulting service' and to be able to write for advice, additional information or assistance in duplicating your Howard Manual TVRO Terminal. I understand you are limiting assistance to those individuals who follow your plans precisely and will not advise on parts substitutions or circuit changes. My check/money order for $25 (made out to H.T. Howard) is enclosed:

My Name ____________________
Mailing Address ____________________
Town/City ____________ State ________ Zip ________

I further understand this advisory/consulting service extends only to myself as a purchaser of your Manual and does not extend to others who may have shared my Manual.

Sincerely - ____________________ Date Submitted ____________

For Howard Use: Date Accepted - ____________
File Number - ____________
Letter History ____________

SUPPORT MATERIALS

To produce this Howard Terminal Manual Bob Cooper spent two days with Taylor Howard at his Northern California home inspecting and detailing the Howard Terminal. During this visit a video tape 'tour' of the Howard Terminal was prepared.

The Howard Terminal Videotape is available on either VHS or Beta format 1/2" cassette. Standard recording format is in the 4 hour (slow speed) form for VHS and the Beta version runs on an L500 tape (two hours normal). This videotape visit takes you through the complete Howard Terminal, from antenna to LNA to receiver to performance and operation with Taylor Howard as host. If you have access to either a VHS or a Beta format machine, this videotape visit with Taylor Howard is the perfect 'supplement' to the Howard Terminal Manual. We believe you will gain valuable insight into the operation of the Howard Terminal through this videotape.

Additionally, during the Satellite Private Terminal Seminar (SPTS '79), held in Oklahoma City August 14-16 (1979) Taylor Howard appeared on the Seminar program to describe his receiver design and to answer questions from attendees about how the receiver works. A videotape (again, VHS or Beta format, 1/2") is available (after September 1, 1979) of this appearance at SPTS '79.

Finally, for those who have not also ordered the COLEMAN TD-2 CONVERSION MANUAL from Satellite Television Technology, it is highly recommended since Bob Coleman has approached many of the problems faced by Taylor Howard from a different perspective. If you do not intend to duplicate the Howard Terminal exactly, the Coleman Manual may well be very useful to you in creating your own 'custom' TVRO terminal.

Note: You do not have to use this order form. If you elect not to use this form, please be sure all of the essential information asked for here is contained in your letter.

ORDER FORM - SUPPORT MATERIALS

___ $75 enclosed for VHS version of Howard Terminal Videotape.
___ $70 enclosed for BETA version of Howard Terminal Videotape.
___ $75 enclosed for VHS version of Howard's Appearance at SPTS '79
___ $70 enclosed for BETA version of Howard's Appearance at SPTS '79
___ $30 enclosed for COLEMAN TD-2 CONVERSION MANUAL

Total Enclosed - $____________________

Ship to:

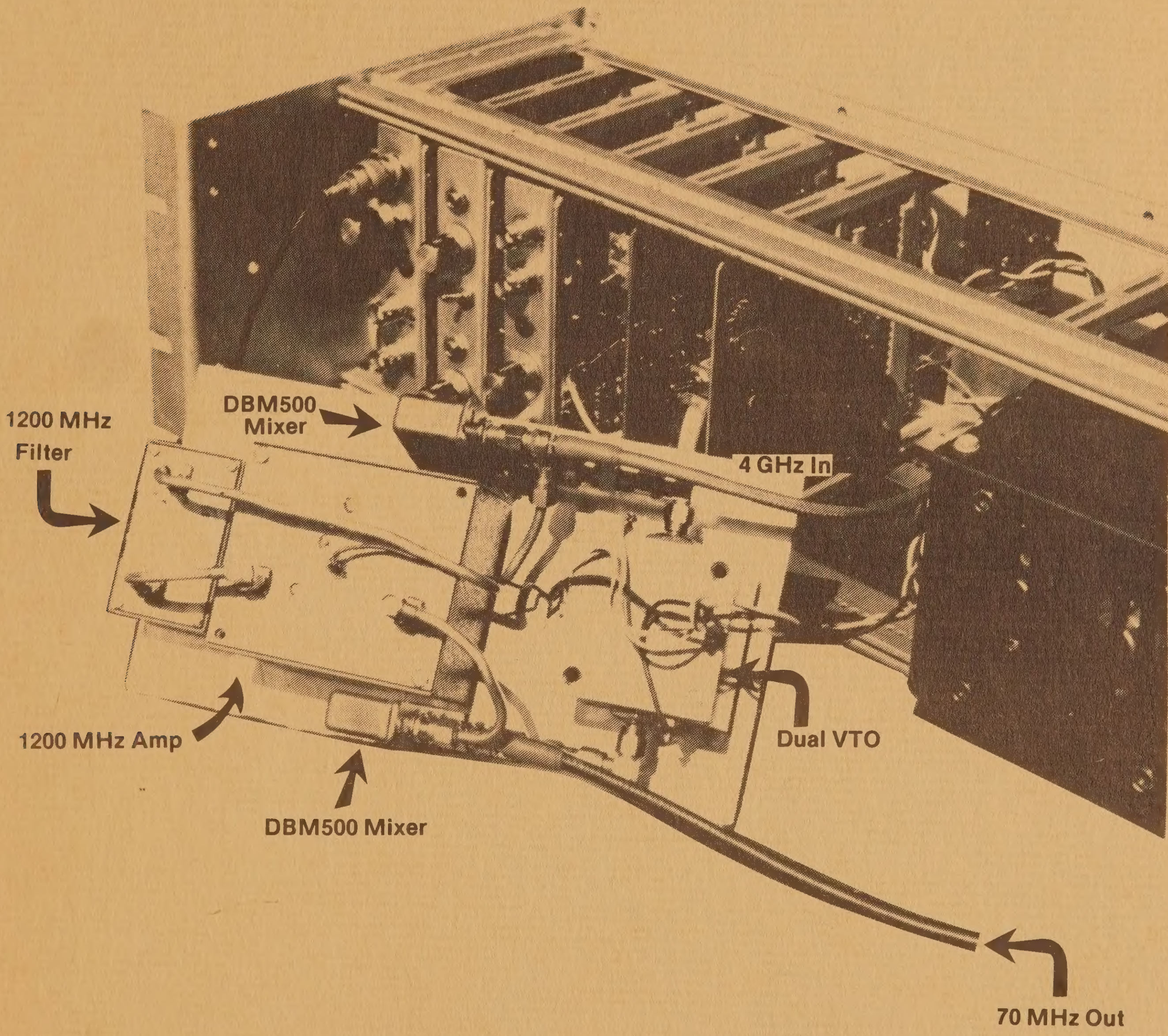
Name ____

Address ____

City/Town ____________________ State ____________ Zip ____________________

Make check payable to: Satellite Television Technology
P.O. Box G
Arcadia, Oklahoma 73007

NOTE: California address in Napa is mail shipping depot only; all telephone queries must come to Arcadia office at 405-396-2574.



THE HOWARD TERMINAL 4 GHz TO 70 MHz RF PORTION